INVESTIGATION ON QUALITY CONTROL FOR CONCRETE MAKING MATERIALS USED IN COST EFFICIENT HOUSING PROJECT:

(IN THE CASES OF AKAKI KALITY)

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By

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CERTIFICATE

This is to certify that Mrs. Mekdese Tesema Meseret entitled'' **Investigation on Quality Control for Concrete Making Materials Used in Cost Efficient Housing project in the Case of Akakai Kality Housing Project''** and submitted in fulfilment of the requirement for the degree of master of Science in civil engineering (COTM), complies with the regulation of university and meets the accepted standards with respect to originality and quality.

Date of defense: June **05, 2018**

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Declaration

The under signed declare that this thesis entitled ***"INVESTIGATION ON QUALITY CONTROL FOR CONCRETE MAKING MATERIAL USED IN COST EFFICIENT HOUSING PROJECT IN THE CASE OF AKAKAI KALITY HOUSING PROJECT''*** is my original work and completed by myself, with the guidance of my advisor, this thesis has not been presented to any other university and is not concurrently submitted in the candidature of any otherdegree. Further I certify that this work is free of plagiarism and all materials appearing in this thesis have been properly quoted and attributed

Name: Mekdese Tesema

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Lists of Abbreviation

LCH	Low Cost Housing
A.A.H.P	Addis Ababa Housing Project
EiABC	Ethiopian Institute of Architecture, building construction and city development
EBCS	Ethiopia Building Code of Standard
ES	Ethiopian standard
IS	Indian standard
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
OPC	Ordinary Portland cement
PPC	Portland Pozzolana Cement
UN	United Nation
MPa	Mega Pascal
f_{ck}	Characteristic Compressive Strength
MSE	Micro Small Enterprises
SD	Standard Deviations

ABSTRACT

Concrete is the most widely used construction material in the world. Good concrete, whether it is plain, reinforced or prestressed, should be strong enough to carry superimposed loads during its anticipated life. To deal about good quality concrete, quality control plays a significant role because qualities of these ingredients and their production process could affect the overall quality of buildings to a higher extent. The study focusing on Investigations on quality control for concrete materials has been conducted in projects administered by Addis Ababa Housing Project found in koye fetch sites.

The research is carried out by collecting data on qualities of ingredients and method of production through questionnaires and observation and sample compressive strength test result from consultant data file to check their compliance with the help of statistical analysis and minimum strength requirement set on recommended standards and comparing result found with Ethiopia Standard and for best decision making purpose Mat lab was used. According to Ethiopia Code of Standard there was compliance and noncompliance, from statistical analysis the mechanism. The findings of the investigation have shown that in all construction sites, sufficient tests are not conducted for all ingredients used for production of concrete. Among those ingredients, sand testes by some sites for its silt content using jar test, observation and or both. In addition to this, handling of those ingredients were very poor, during observation intermixing coarse and fine aggregate, grass grown on the top of sand, were shown and production process also not conducted properly as specified in the recommended standards. Quality problem will occur when cement is in contact with damp air or moisture it sets more slowly and has less strength than cement that is kept in dry condition, presence of soft particles and organic materials in combination with aggregate may form a coating and may weaken the bond between cement paste and aggregate. The amount of water cement ratio in the concrete must be maintained in order to produce good quality concrete otherwise poor quality will produce.

Key Terms: Quality Control, Compliance, Compressive Strength, Ethiopian standard, Cost efficient housing.

CHAPTER ONE

INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Africa cities have growth rates of up to 5% per year: which makes them the fastest growing cities in the world today (Zegeye and Helaei, 2012). Extrapolations show that the urban population in Africa currently doubles every 10 to 15 years. Ethiopia confronted with a population increase of 45 million people over the next 15 years. The concept of grand housing project in order to achieve sustainable urban development regulations has to be produced by using locally available construction materials. The population increase of 20% in the last decade in Addis Ababa has dramatically illustrated. It has neither been possible to develop infrastructure and homes for a fast growing population nor to establish a sustainable means of existence for the new comers to the city. As a solution for the desperate situation, the low cost housing (LCH) was developed with the support of German. Since its introduction in to the local construction sector in 2002, it has led to visible results. The recently launched "Addis Ababa Grand Housing Program" an ambitious project aimed at the construction of further 50,000 accommodation units per year until 2014 (Zegeye and Helaei, 2012).

Grand housing program is currently the hope of many dwellers; koye fetch construction project site is one of and will be expected to answer the question of the Addis Ababa residents. This project site covers total area of 556 hectare (ha). (Akaki Kality Project Branch Office as of March, 30 2010). It consists of housing units that are transferred to users called 10/90 (G+2 and G+4), G+2 403 building (9704 housing units and 8 G+4 (200 housing units) and units that are

expected to be distributed at end of Ethiopia fiscal year. The total number of blocks and units found in koye fetch are of 577 blocks (23901 units) G+4 and 494 blocks (26211 units) G+7. Total of 1,071 blocks or 50,112 units that means it covers one city. 250,560 dwellers are expected to live there. The project is divided in to packages 2A and 2B the division is based on the projects that are expected to transfer the units to the dwellers the first package that is 2A is expected to finish 100% and the second package is expected to finish 80%. (Akaki Kality Project Branch Office as of March, 30 2010).

Table 1.1.Sites which are expected to be reach 100% as package 2A (20/80) G+ 4 and G+ 7

Item no.	Project Branch Office	Number of Blocks	Number of Housing Units	Current Physical Progress
1	Akaki Kality Housing Project Construction Branch Office	340	10,954	90.48%
2	Project 18	119	6,568	80.01%
3	Project 11	118	6,379	70.43%
	Total	577	23,901	**84.22%**

Table 1.2. Sites which are expected to be reach 80% as package 2B (20/80) G+ 4 and G+ 7

Item no.	Project Branch Office	Number of Blocks	Number of Housing Units	Current Physical Progress
1	Project 16	125	6,326	73.9%
2	Addis Ketema	121	6,331	70.52%
3	Project 17	124	6,927	64.44%
4	Project 12	124	6,627	64.72%
	Total	494	26,211	**68.39%**

Source (AAHCPO, March 30/2010 Project Status Report)

From the expected sites to be transferred the units to the dwellers from first package that is 2A is expected to finish 100% is Akakai Kality Housing Development Project Branch Office is one of them. This project site covers area about 138.83 ha and the total numbers of blocks are 340, consisting of 317 G+4 and 23 G+7 and 10,954 housing units. The project was started May 2014. From point of hugeness of the project there are two consulting firms that entered contract to administer and supervise the construction project. These consulting firms are grade one. And the numbers of blocks they administer are 156 G+4 and 15 G+7 total of 171 by Perfect consulting and 161 G+4 and 8 G+7 by Virtual consulting total of 169. There are 10 types of typologies which are divided in to old and new. The typologies are as following:

X1, L1, L2, O-S, F-S, F-L } G+4

S-S, S-L, O-S, O-L } G+7

Table1.3. Blocks under construction with their respective typology and room

BLOCKS UNDER CONSTRUCTION WITH THEIR RESPECTIVE ROOMS																	
Block Typology	Total No of Blocks	No of Blocks with out shop	No of Blocks with shop	House Hold types without shop				House Hold types with shop					House Hold types				
				Per Block				Per Block					Total				
				Studio	1-Bed Room	2-Bed Room	3-Bed Room	Studio	1-Bed Room	2-Bed Room	3-Bed Room	Shops	Studio	1-Bed Room	2-Bed Room	3-Bed Room	Shops
	G + 4																
X-1	65	65	0	5	10	10	5						325	650	650	325	
L-1	142	82	60	5	15	5	5	5	12	5	5	3	710	1950	710	710	180
L-2	90	20	70	5	5	10	5	5	8	4	4	6	450	450	760	380	420
O G+4 Straight	14	14	0		21	9	10						0	294	126	140	
FG+4 Straight	6	6	0		20	10	10						0	120	60	60	
TOTAL G+4	**317**		**130**										**1485**	**3464**	**2306**	**1615**	**600**
	G + 7																
O res Straight	7	5	2	0	64	32	32		28	16	16	4	0	224	112	112	
S L-Shape Shop	6	0	6						60	32	28	8	0	180	96	84	24
O L Shap	3	3	0	0	32	16	16						0	96	48	48	0
S Res Stright Shop	7	1	6	0	32	16	16		60	32	28	12	0	212	112	100	36
TOTAL G+7	**23**	**9**	**14**										**0**	**712**	**368**	**344**	**60**
BLOCKS													**1485**	**4176**	**2674**	**1959**	**660**
Total Residential Housing Units				**10,294**			**Total Shops**			**660**			**Total Resid. & Shops**			**10,954**	

(Source: Akakai Kality Construction Project Progress Report)

Therefore, in order achieve goal the type of concrete making materials covers the most. Those materials have to fulfill the required specification and requirement. Concrete is the most widely used construction material in the world. It is a material that literally forms the basis of our modern society. It is a mixture of binding material (cement), fine aggregate (sand), coarse aggregate (gravel), admixtures when special properties are desired and water in predetermined proportions. These ingredients play significant role in fulfilling the fundamental requirement for making concrete structures and the structure has to fit with the standard requirement in order to produce good quality concrete. Good concrete, whether it is plain, reinforced or prestressed, should be strong enough to carry superimposed loads during its anticipated life. Other essential properties include impermeability, durability, minimum amount of shrinkage and cracking (Taylor, 1977).

There are different type of construction project that need involvement of many participants including the client, consultant, contractor, and micro enterprises. Each of these participants involved in implementing quality in construction projects. These participants are both influenced by different things and depend on each other in addition to environmental situation that affect the construction process. Therefore, the construction projects have become more complex and extensive efforts are required to improve the construction quality and overall organizational performance associated with cost and time (Chung, 1999). In any construction project quality is an important issue. The owners/ clients in construction industry require that the quality of the product should meet the stated standard and specifications. There are many factors that affect the quality of a product and thus the project parties can be exposed to many loses. Condominium housing is one of the mega projects in Ethiopia that means it need emphasis from all stake holders in order to achieve it goal. Due to many quality problems the construction of

condominium is facing different challenges from different dwellers in Addis Ababa. Therefore, this study will investigate the quality control for concrete materials used in AAHCPO in the case of Koye fetch, the procedure that they have used in production in relation to test result. From point of solving questions of dwellers this research studied emphasis must be given from material selection, production process up to testing.

1.1.1. Definition of Key Terms

- "Concrete may be considered as being composed of four basic separate ingredients: cement, coarse aggregate, fine aggregate and water. It is as a grade mixture of fine and coarse held together by wetted cement. Another way of viewing concrete is that the coarse held together by mortar that is composed of cement, fine aggregate and water. The requirement of concrete are but the ultimate aim is to produce most economical combinations of concrete materials that will satisfy the performance requirement and specifications.''(IRVING, 2010)
- Standard**: -** a document, established by consensus and approved by a recognized body. that provides for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.
- Procedure**: -** a specified method of carrying out particular task.
- Non-Conformity**: -**the non-fulfillment of specified requirements.
- Quality control**:-**The operational techniques and activities that are used to fulfill requirements for quality. Or it may also be defined as: a system for insuring quality of output involving inspection, analysis, and action to make required changes.
- Inspection& test plan: - A document, which identifies the inspection, testing/verification and acceptance requirements for each activity of the construction process.

- Quality Control: - comprises a combination of actions and decisions taken in compliance with specifications and checks to ensure that these are satisfied. Quality consists of two distinct but interconnected parts, namely production control and compliance control.
- Production Control: - comprises a combination of actions and decisions taken during production to check the operation and to obtain a reasonable assurance that the specification will be satisfied.

Procedures in production control

- Inspection of materials (ingredients) on site to check the compliance with the requirements of specifications;
- Inspection prior to production;
- Controlling during/under construction;
- Finally follow up information of construction procedures (a site book shall be kept, having the information).

- Compliance control: - comprises a combination of actions and decisions, in accordance with compliance rules adopted in advance, to check the compliance of a product with the specifications

Concrete: - is a versatile and most popular construction material in the world. It is produced by mixing fine and coarse aggregates, cement, water and additives in a certain prescribed proportion. Aggregates are known to be particles of rock or equivalent which, when brought together in a bound or unbound condition, form part or whole of an engineering or building structure. Aggregates, both fine and coarse, take about 65-75% by volume of concrete and are important ingredients in concrete production. The parent material of aggregates is derived mainly from volcanic activity. The dominant rock for coarse aggregate production in Ethiopia is

generally basalt while ignimbrite is most commonly used for masonry stone. On the other hand the majority of sand is collected from riverbeds. (Eshetu, 2005)

1.2. STATEMENT OF THE PROBLEM

In Addis Ababa the construction of condominium is exposed to high complain from house occupant while the households entirely delivered and also response came from the house occupants the level of the quality of the houses is poor in terms of its construction (Hiwot, 2012). Besides to the literature findings, the study experience in the construction of condominium in AAHCPO observed the concrete material handling, mixing, transporting, placement, vibrating, curing testing and limited knowledge of workmanship had some the problems. Thus related to quality control for each ingredients for concrete work should be properly addressed to solve the quality related problems of concrete materials in AAHCPO.

High prevalence of urban poverty and high urban unemployment rate in major Ethiopian cities triggered the government of Ethiopia to set immense low cost housing strategies to alleviate such huge problems in the cities, because only 30% of the urban house stock was regarded to be in fair condition and the housing shortage is being estimated to be between 900,000 and 1000,000 (MOWUD, 2008). In Addis Ababa alone, 300,000 houses were required to meet the housing deficit of the city (UN-HABITAT, 2011). Yet, according to data obtained from Commercial Bank of Ethiopia (CBE) in August 2013 alone around 900 thousands home seekers were registered for condominium houses. However, the project office up to August 2016 constructed and transferred only 179 thousands of condominium houses to city dwellers in Addis Ababa, which is contributed only around 20% of the total demand (CBE and AAHCPO, 2016).

This indicates that there is a huge gap between the housing supply and demand in Addis Ababa city and the project office is unable to satisfy those registered dwellers and they are still

waiting for chances to get condominium houses. Therefore, the housing deficit is set to increase concurrently with the foreseen high population and urbanization growth (UN-HABITAT, 2011).Reserving house deficit all those housing units has to have quality as per the required standard and specification. So that the requirement are satisfied. In order to talk about quality of the concrete in order to cast of different parts of the building structure. The ingredients are useful for production of precast beam units, beams, columns, to cast suspended slabs etc. Therefore, this research investigates the quality control for concrete materials in cost efficient houses administer by Addis Ababa Housing Project.

1.3. RESEARCH QUESTIONS

1. What are the current practices implemented in AAHCPO on the quality control of concrete making materials?
2. What are the procedures used to control the quality of concrete making materials on cost efficient housing in the cases of AAHCPO?
3. What factors drive contractors to produce low quality construction concrete material in AAHCPO?

1.4. OBJECTIVE OF THE STUDY

The study has the following general and specific objectives.

1.4.1. General objective:

The general objective of this thesis investigation on quality control for concrete materials used in cost efficient house in Addis Ababa Housing Project Office.

1.4.2. Specific objectives:

1. To investigate the current practices implemented in AAHCPO on the quality control of concrete making materials.
2. To explore the procedures used to control the quality of concrete making materials on cost efficient housing in the cases of AAHCPO.
3. To identify the major factors that drive stakeholders to produce lower quality construction concrete materials in AAHCPO.

1.5. SIGNIFICANCE OF THE STUDY

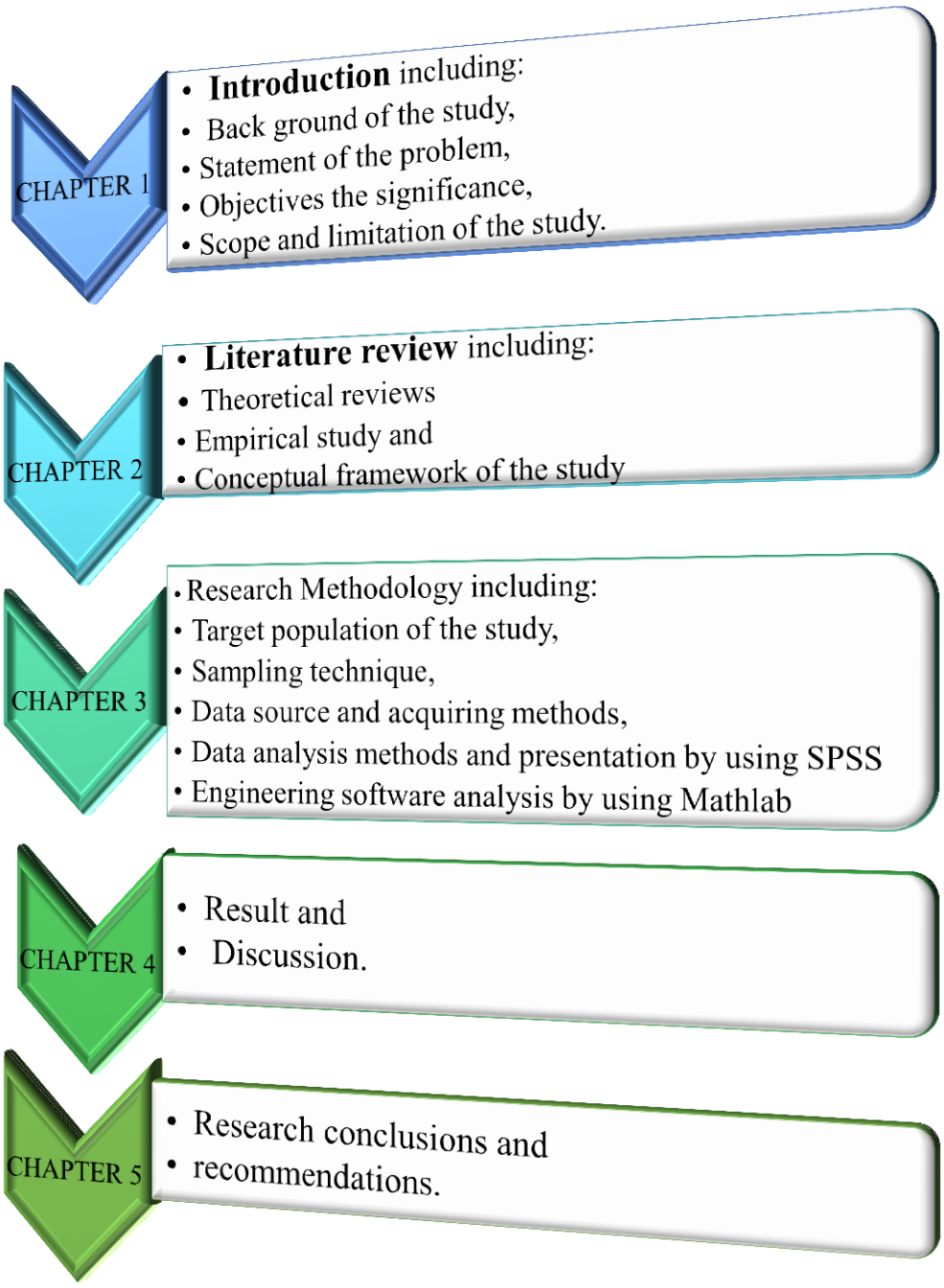
Construction of condominium house is mega project that contribute solution to peoples who need house on the potential they can pay. In order to satisfy their need the quality of the houses must satisfy the standard that is why this paper is mainly focus on the condominium houses in which the quality of concrete materials had been studied. From this thesis the stakeholder such as consultants, contractors and government staffs are the first beneficiaries and the users also be benefit from the research outcome. And this helps the consultants in specifying the effective and suitable quality control system. Because quality control is one of the significant factors that affect the quality of products. Selecting efficient quality control system helps to assure the strength of the structure, safety of occupants and to increase the quality of product,

reducing the cost incurred due to poor quality of work and material. The thesis will be used as a reference material for future researchers interested to conduct research in the study area.

1.6. SCOPE AND LIMITATION OF THE STUDY

The study addressed the stated objectives of the research and tried to investigate the quality control for concrete making materials in building projects administered by Addis Ababa Housing Project based on the existing theories and principles. Constructions of condominium housing units are many in number in order to answer the citizen question. From those sites that are divided in to different packages. Koye fetch project site includes those project packages that are divided in to package 2A, 2B and 3A etc. From projects that aree expected to be transferred to dewllers one of the most hope giving site is Akakai Kality project site and most of complied and well organized information are expected to be gathered and issues related to investigation on quality control for concrete materials were expected to be safely examined. Therefore, Akakai Kality construction project site were selected and investigation was undertaken on this selected sites located in Addis Ababa. The research was conduct by collecting data from the year 2014-2018 on koye fetch construction site specifically Akaki Kality project branch office. Generally this site currently extensive building has been undertaken by constructing thousands of units for condominium building and they are owned by Addis Ababa Housing Project Office (AAHCPO) and sample test results that are taken from footing pad, ground elevation column, first to seventh floor slab and top tie beam were collected for investigation purpose. Test results that are analyzed are limited to 7^{th}, 14^{th}, 28^{th} and 45^{th} days.

1.7. Organization of the Study



CHAPTER TWO

LITERATURE REVIEW

2.1. General

This chapter focuses on different literature reviews available on quality control for concrete materials selection, handling, batching, transporting, placing, compacting, curing and testing that was taken from different journals, articles, thesis papers and books. Therefore, this chapter mainly focuses on the quality of those concrete materials in relation to physical and chemical as well as workmanship that intensively affect the quality of concrete.

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in hard matrix of material (the cement of binder) that fills the space between the aggregate particles and glue them together (Sydney, Francis and Drawin2013**).** The binder or matrix is a combination of cement and water; it is commonly called the "cement paste. Aggregates are essentially filler materials that can be separated into fine and coarse aggregates. In addition to aggregates and binders, there is another material called additive which may be used in concrete to improve certain of its properties (Eshetu,2005).

The production of concrete involves two distinct but equally important activities. One is related to material required for concrete production such as selection and proportioning of ingredients and the other is the process involved in its production such as batching, mixing, transporting, placement, compaction and curing (Sydney, Francis and Drawin2013).To produce concrete as economically as possible with appropriate workability, strength and durability care has to be taken during concrete production because poor quality of concrete even from well-designed mix can be happen due to lack of attention in production (Sydney, Francis and Drawin2013). A good and a bad concrete may be made from exactly the same ingredients if there is a difference on the quality control during production. The importance of quality of concrete is being increasingly realized to derive the optimum benefit from the materials employed. Quality control does not merely signify testing of concrete cubes at 7^{th}, 14^{th} 28^{th}, 45th days etc.; rather it actually spread throughout all aspects of the choice of materials, design, and

workmanship it commences much before any concrete is available for testing at 28 days (Duggal, 2009).

Quality concrete is that which is capable of meeting the requirements of the job in terms of strength, durability and appearance. Strength is often the major feature in defining the quality because strength is both easy to define and to measure. Therefore in many cases, strength is the unique measurement of concrete quality (Gupta and Gupta, 2004).

From production point of view Inspection of materials on site shall be made at delivery to check compliance with the specifications and the requirements of EBCS Code of (Chapter 8). One of the compliance criteria for condominium houses is compressive strength test. It is an established fact that the compressive strength of concrete is influenced by the quality and proportion of fine and coarse aggregate, the cement paste and the paste-aggregate bond characteristics. These, in turn, depend on the macroscopic and microscopic structural features including total porosity, pore size and shape, pore size distribution and morphology of the hydration products, and the bond between individual solid components. Other qualities of concrete such as durability and abrasion resistance are also highly dependent on the aggregate, which in turn depends on strength of parent rock, purity, surface texture, gradation and so on.

In order to get quality concrete the most important thing is obtained by skilled supervisors and well trained workers who understand the science of concrete. Hence, the workmanship of concreting operations is therefore important in maintaining the required concrete quality. The specifications should also contain sufficient information on the workmanship requirements as well as on materials to maintain satisfactory supervision. A good level of supervision helps to improve the standard of workmanship on the site (Tahir, 1989).

Literatures pertaining to similar studies conducted all over the world are collected from various sources to determine the feasibility and scope of the work. Similar studies undertaken are as follows:

2.1.1. Concrete Constituents

2.1.1.1. Portland Cement

Portland cement was first made in Portland, England, from which it derived its name, by (Joseph Aspdin 1824). It can be produced either by a wet or a dry process (IRVING, 2010).

Cement is used for making concrete; it is finely powder and all having the important property that when mixed with water a chemical reaction (hydration) takes place. In the early stage of hydration, while in its plastic stage, cement mortar gives to the fresh concrete its cohesive properties. A very hard and strong binding medium for the aggregate particles produced. Worldwide produced Portland cements are many of them are used for specific purpose. Among them the common cement types are ordinary and pozzolana Portland cement, OPC PPC and these types of cement are mostly produced in Ethiopia.

- Concrete is prepared by mixing cement (binder), sand (fine aggregate), gravel (coarse aggregate) and water with specific proportions.
- The cement and the water will react through the hydration process. The hydrated cement composed of four major compounds namely, tri-calcium silicate (C_3S), di-calcium silicate (C_2S), tri calcium aluminate (C_3A) and tetra calcium alumino ferrite (C_4AF). The most important products of the hydration reaction are the calcium silicate hydrate (C-S-H) and the calcium hydroxide (CH). The hydration reactions of the major compounds can be written as below:

$$2C_3S+6H \rightarrow C_3S_2H_3+Ca(OH)_2$$

$$2C_2S+4H \rightarrow C_3S_2H_3+Ca(OH)_2$$

$$C_3A+6H \rightarrow C_3AH_6$$

$$C_4AF+ 2Ca(OH)_2+10H \rightarrow C_3AH_6+C_3FH_6$$

a. Ordinary Portland cement (Type I): is admirably suitable for use in general concrete construction when there is no exposure to sulphates in the soil or groundwater. Ethiopian Standard ES1177-1:2005 specify three classes of standard strength having two types of early strength such as N type (ordinary early strength) and R type (high early strength). The standard compressive strength of cement shall conform the requirements in the Table 2.2.1.1.below

Table 2.1. Compressive strength of cement [Ethiopia Standard 1177-1:2005]

Strength Class	Minimum strength, MPa At the age of			maximum strength MPa, at the age 28days
	Early Strength		Standard Strength	
	2 days	7 days	28 days	
32.5 N	-	≥16	≥32.5	≤52.5
32.5 R	≥10	-		
42.5N	≥10	-	≥42.5	≤65.8
42.5 R	≥20	-		
52.5 N	≥20	-	≥52.5	-
52.5 R	≥30	-		

b. PPC is economical because costly clinker is replaced by cheaper pozzolanic material. It has also durability characteristics than OPC particularly in hydraulic structures because soluble calcium hydroxide is converted into insoluble cementitious products resulting in improvement of permeability. PPC generates reduced heat of hydration and that too at a low rate. The long term strength of PPC beyond a couple of month is higher than OPC if enough moisture is available for continued pozzolanic action (Neville and Brooks, 2002).

The right quality and optimum percentage of fly ash used in Portland Pozzolana Cement has considerable advantages over OPC. The advantages of PPC are mainly due to the slow conversion of calcium hydroxide($Ca(OH)_2$)in the hydrated cement paste into cementcious product.

The 28 days minimum strength in MPa gives the name of the classes, moreover, cement of class 32.5 and 42.5 are each subdivided into two subclasses, one with an ordinary early strength, and the other with a high early strength. The two subclasses with a high early strength denoted by the letter R, are rapid hardening cements and the other one with normal strength with denoted by the letter N.

i. Rapid hardening Portland cement

This cement comprises Portland cement subclasses of 32.5 and 42.5 MPa as prescribed by [ES 1177-1:2005].Rapid hardening Portland cement, as its name implies, develops strength more rapidly, and should, therefore, be correctly describe as high early strength cement. The use of it is indicated where a rapid strength development is desired, e.g. when the formwork is to be removed early for re-use, or where sufficient strength for further construction is wanted quickly as practicable. Rapid-hardening Portland cement should not be used in mass construction or in a large structural section.

At the Addis Ababa Housing construction project the type of cement that is provided to contractors is both 42.5 and 32.5 strength class cement type was confirmed by looking cement bag found in site in the case of koye fetche project site. The following important physical properties of cement are discuss as follow:

2.1.1.2. Physical Tests

a. Particle Size and Fineness: in order to accelerate strength development and reduce bleeding at a time of vibration fineness is very important. So that approximately 95% of cement particles are smaller than 45 micrometers, with the average particle around 15 micrometers on the study he took. (Steven 2003)
b. Soundness: It is a very important test to assure the quality of cement since unsound cement produces cracks, distortion and disintegration, ultimately leading to failure due to large change in volume after setting Duggal, (2000). According to Ethiopian standard ES1177-1:2005 and Indian standard IS 8112:1989, soundness or expansion of cement is limited to 10 mm. In case failing to meet the above requirement Indian standard recommends to conducting further test on another portion of the same sample after aeration, the aeration shall be by being spread out to a depth of 75 mm at a relative humidity of 50 to 80 percent for the total of 7 days and their expansion shall not more than 5 percent.
c. Setting Time: the minimum initial setting time specified by the standard is 45 minutes.

Table 2.2. Physical Tests &Testing Frequency (Ephrem, 2014)

			Autocontrol testing			
Property	Comments to be tested	Test method [a][b]	Minimum testing frequency		Statistical assessment procedure	
			Routine production	Initial period for a new type of cement	Inspection by	
					Variables [c]	Attributes
1	2	3	4	5	6	7
Early strength Standard strength	All	EN 196-1	2/week	4/week	x	-
Initial setting time	All	EN 196-3	2/week	4/week	-	x [d]
Soundness (Expansion)	All	EN 196-3	1/week	4/week	-	x
Loss on ignition	CEM I, CEM III	EN 196-2	2/month [e]	1/week	-	x [e]
Insoluble residue	CEM I, CEM III	EN 196-2	2/month [e]	1/week	-	x [e]
Sulfate content	All	EN 196-2	2/week	4/week	-	x [e]
Chloride content	All	EN 196-2	2/month [e]	1/week	-	x [e]
Pozzolanicity	CEM IV	EN 196-5	2/month	1/week	-	x
Composition	All	- [f]	1/month	1/week	-	
Heat of hydration	Low heat cement	EN 196-8 & 9	1/month	1/week	-	x

2.1.1.3. Chemical Tests

Chemical tests are normally conducted by the manufacturer on regular basis in order to check the quality of the product. They may also be conducted in research laboratories in order to determine the compound composition of cement used in a particular research.(Mikyas ,1987).

Table 2.3. Chemical Requirement (Ephrem, 2014)

1	2	3	4	5
Property	Test reference	Cement type	Strength class	Requirements [1]
Loss on ignition	ES 1176-2	CEM I CEM III	all	≤ 5,0 %
Insoluble residue	ES 1176-2 [3]	CEM I CEM III	all	≤ 5,0
Sulfate content (as SO_3)	ES 1176-2	CEM I CEM II [4] CEM IV CEM V	32,5 N 32,5 R 42,5 N	≤ 3,5
			42,5 R 52,5 N 52,5 R	≤ 4,0
		CEM II [5]	all	
Chloride content	ES 1176-6	all [6]	all	≤ 0,10 %[7]
Pozzolanicity	ES 1176-5	CEM IV	all	Satisfies the test

2.2. Cement storage and Handling

Exposing cement to moisture or damp air has an effect on long term strength development cement stored in contact with damp air or moisture, sets more slowly and has less strength than when concrete is exposed to dry condition. In order to reduce air content and moisture in storage house the better thing to is that closing all the openings, cracks and roofs. It should not be stored in damp floor and it has to rest on flat plat form and should be stacked together in order to reduce air circulation and the distance between the vertical supporting wall and cement bag has to be with in the allowable limit. (Steven, 2003) In addition its arrangement should follow first in first out method. Ethiopian standard **(**ES 1177-1:2005) limit 8 bags high and protected by waterproof

structure. On the other hand American Committee Institute, ACI 2009 recommended 14 and 7 layers depends on their storage period in stock of less than or greater 60 days by providing proper air circulation.

2.3. Mixing water

Since this research is mainly focused on concrete making materials, the discussion made concerning water is not detailed. comparing both the setting time and the compressive strengths of specimens made with the appropriate cement and both the water in question and distilled water.

However water of doubtful quality should be submitted for laboratory analysis and tests. Water should be avoided if it contains large quantities of suspend solids, excessive amounts of dissolved solids, or appreciable amounts of organic materials (ACME,1995). In addition, the amount of water used should be the minimum necessary to ensure thorough compaction of the concrete (Adafin et al, 2010).

The water is considered to be suitable if it neither changes the setting time by more than 30 min, nor reduces the strength by more than 20% compared to the specimen made with distilled water. The mixing water, that is, the free water encountered in freshly mixed concrete, has three main functions:

(1) It reacts with the cement powder thus producing hydration;

(2) It acts as a lubricant, contributing to the workability of the fresh mixture;

(3) It secures the necessary space in the paste for the development of hydration products. The amount of water needed for adequate workability is practically always greater than that needed for complete hydration of the cement.

Water is used in concrete making for three different purposes:

i. As mixing water;
ii. For curing of concrete;
iii. For washing aggregate.

The quality and requirements for the water depend on the type of the Summaries of the physical and physicochemical use.

i. Mixing water

Water quality is the constituents of concrete but water quantity, as it affects the free/water cement ratio, is most important for control of consistence, strength and durability. Water used for concrete mixtures should contain no substance which can have an appreciably harmful effect on strength or upon durability of the concrete in service (Troxel, and Davis ,1956). Substances in water which, if present in large amounts, may be harmful are:

- ✓ salt,
- ✓ oil,
- ✓ industrial wastes,
- ✓ alkalis,
- ✓ sulphates,
- ✓ organic matter,
- ✓ Silt, sewage etc.
- ✓ Tests by the sense of smell,
- ✓ Sight or taste would reveal such impurities;

ii. Water for curing of concrete

The requirements for curing water are less stringent than those discussed above, mainly because curing water is in contact with the concrete for only relatively short time. Such water may contain more inorganic and organic materials, sulphuric anhydride acids, chlorides, and so on, than acceptable mixing water, especially when slight discoloration of the concrete surface is not objectionable. Nevertheless, the permissible amounts of the impurities are still restricted, in cases of any doubt, water samples should be sent to a laboratory for testing. (Eshetu, 2005)

iii. Water for washing aggregate

Water for washing aggregate should not contain materials in quantities large enough to produce harmful films or coatings on the surface of aggregate particles. Essentially the same requirement holds when the water is used for mixing and cleaning concrete. Other concreting

Chemical limitations for the impurities equipment in wash water are specified in ASTM C 94-8913.

2.4. Aggregate

Aggregate is much cheaper than cement and maximum economy is obtained by using much aggregate as possible in concrete. It's also considerably improves both the volume and the durability of the resulting concrete. Natural aggregate are formed by the process of weathering and abrasion, or by artificially crushing a large parent mass.

2.4.1. Basic characteristics of aggregate

The criterion for a good aggregate is that it should produce the desired properties in both the fresh and hardened concrete.

2.4.1.1 Physical properties

The properties of the aggregate known to have a significant effect on concrete behavior are:

i. Strength

The strength of an aggregate limits the attainable strength of concrete only when its compressive strength is less than or of the same order as the design strength of concrete. In practice the majority of rock aggregates used are usually considerably stronger than concrete. While the strength does not normally exceed 80 N/mm^2 and is generally between 30 to 50 N /mm^2 the strength of aggregate commonly used is in the range 70 to 350 N/mm^2**.** In general igneous rocks are very much stronger than sedimentary and metamorphic rocks. Because of irregular size and shape of aggregate particles a direct measurement of their strength properties is not possible **(**M. S. Shetty1982).

ii. Deformation

The deformation characteristics of an aggregate are seldom considered in assessing its suitability for concrete work although they can easily determine from compression tests on specimens from the parent rock. In general, the modulus of elasticity of concrete increases with increasing aggregate modulus. The deformation characteristics of the aggregate also play an important part in the creep and shrinkage properties of concrete as the restraint afforded by the aggregate to the creep and shrinkage of the cement paste depends on their relative modulus of elasticity. (Tesfalem, 2014)

iii. Toughness

Is its resistance to failure by impact and this is normally determined from the aggregate impact test British standard (BS 812). Since the apparatus is portable, cheap, simply to operate and rapid in application it can be used in the field for quality control purposes.

iv. Hardness

It is the resistance of an aggregate to wear and is normally determined by an abrasion test (BS812). Toughness and hardness properties of an aggregate are particularly important for concrete used in road pavements.

v. Volume change

Is due to moisture movements in aggregate derived from sand stones, greywacke and some basalts may results in considerable shrinkage of the concrete. If the concrete is restrained this produces internal tensile stresses possible tensile cracking and subsequent deterioration of the concrete. If the coefficient of thermal expansion of an aggregate differs considerably from that of the cement paste this too may adversely affect the concrete performance. ((Blackledge, 2002).)

vi. Porosity

It is an important property since it affects the behavior of both freshly mixed and hardened concrete through its effect on the strength, water absorption and permeability of the aggregate. An aggregate with high porosity will tend to produce a less durable concrete, particularly when

subjected to freezing and thawing, than an aggregate with low porosity. Direct measurement of porosity is difficult and in practice a related property, namely, water absorption, is measured. The water absorption is defined as the weight of water absorbed by a dry aggregate in reaching a saturated surface- dry state and is expressed as a percentage of the weight of the dry aggregate. **(**M. S. Shetty1982).

2.4.2. Types of aggregate

The general classification of aggregate and the related British standards.

a. Heavy weight aggregate

It provides an effective and economical use of concrete for radiation shielding by giving the necessary protection against X- rays, gamma rays and neutron.

b. Normal weight aggregate

These aggregates are suitable for most purposes and produces concrete with density in the range 2300 to 2500 kg/m^3.

c. Light weight aggregate.

All lightweight materials are relatively weak because of their high porosity, which gives them reduced weight. This imposes a limitation on strength. Lightweight aggregates are used to reduce weight in structural elements or to give improved thermal insulation (Blackledge, 2002).

Light weight aggregate find application in a wide variety of concrete products ranging from insulation screed to reinforce or priestesses concrete, although their greatest use has been in the manufacture of precast concrete blocks. Concrete made with light weight aggregate have good fire resistance properties. Their bulk density normally ranges from 350 to 850 kg/m^3 for coarse aggregate and from 750 to 1100 kg/m^3 for fine aggregate.

Denamo Addissie on his thesis studied and noted that if the aggregates are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the water/cement ratio. Both these conditions are harmful for the quality of concrete. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the water/cement ratio is kept as exactly as per the

design **(**Shetty,1982). Therefore, in calculating or measuring quantities for concrete mix it is important to know the state at which the aggregate is used (Mikyas, 1987). And in his study clearly showed absorption represents the total water contained in the aggregate in the saturated surface-dry condition and the surface moisture (or free moisture) is the water in excess at the saturated surface-dry state. The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. The surface or free moisture content is generally given in terms of percent of the weight of the saturated surface dry **(**Mikyas, 1987**).** The absorption capacity is a measure of the porosity of an aggregate. Approximate values of the absorption capacities of some types of aggregates are given in Table 2.4.

Table 2.4. Absorption Capacity

Material	Absorption capacity % by wt.
Sand	0 – 2.0
Gravel	0.5 – 1.0
Basalt	0 – 0.5
Granite	0 – 0.5
Limestone (firm)	0.5 – 1.0
Sand stone	2 – 7.0
Trap rock	0 – 0.5

A research was carried out to investigate quality control between year May, 2010 and September, 2010 mainly by means of "Questionnaire". Data were collected with the aid of well-structured questionnaires which provided a set of alternative responses from which the respondents selected. The population of this study was made up of construction professionals in the Nigerian building construction industry from the analysis of the investigation carried out and findings made; the study revealed that though, all construction firms acknowledge the need for material quality control on construction sites but it is carried out to a reasonable extent only on large construction sites and by large construction firms, hence strict compliance with standard material control strategies is maintained only by large construction firms. However, it was

concluded that the recognition of material quality control and implementation of the strategies involved by building construction firms would minimize delays, disputes, avoid project abandonment as much as possible, achieve effective project monitoring and control, high construction quality and productivity as well as minimize cost and time overrun in construction process as much as possible. It also enhances profitability of the contractor's organization in the Nigerian building construction industry. This is achieved through the adoption and implementation of well-articulated and cost-effective material control strategies that can guarantee increased productivity. Hence, tasks are completed within planned duration, cost and quality standard (Adafin et al, 2010).

On studies carried out on continued effort by the Washington State Department of Transportation (WSDOT) to pursue and implement new technologies into the construction process to better serve the public. One of these new technologies is concrete maturity. Maturity is an approach to quality control that predicts the strength of the in-place concrete based on its internal temperature. It is a quality control technique for concrete that is firmly grounded in basic concrete fundamentals such as cement hydration and concrete’s response to field conditions such as temperature and moisture. These basic fundamentals include the knowledge that concrete will gain strength faster when cured at higher temperatures and will gain little or no strength when exposed to very cold temperatures. Maturity takes these varying curing conditions in the field into account by measuring and recording the internal temperature of the concrete with special sensors or loggers embedded in the concrete at the time of placement (Krith et al, 2009).

A list of the testing equipment proposed for quality control testing, and the test methods and frequency of calibration or verification of the equipment is required. The equipment shall be provided to perform production control testing and shall be maintained in suitable working order. The equipment is required to be in accordance with AASHTO requirements where applicable. The Contractor is also required to provide a spud vibrator with a power source in suitable working order. The Contractor is required to maintain a record of all equipment calibration or verification results at the testing facility.

On year of 2014 the importance of quality of concrete is being increasingly realized to derive the optimum benefit from the materials employed. Normally, Test specimens indicate potential rather than actual strength of a structure; so that the strength reduction can occur in concrete due to certain factors which makes significant (Sydney, Francis and Drawin2013).

The importance of quality control such as:

- ✓ Materials this include variability in the cement itself, grading, moisture content, mineral composition, physical properties and particle shape of aggregate and in the admixture used.
- ✓ Production process which involves types of batching plant and equipment, method of transporting concrete to the site, and procedures and workmanship used to produce and place the concrete and
- ✓ Testing during sampling procedures, the making and curing of test specimens, and the test procedures used may cause strength reductions which are not reflected in the cube strength results. Therefore, this variability in properties must be considered when preparing concrete specifications. The method that he had used was collection of data by using questionnaire, observation and interview and the result that he had got was satisfactory (Kahsay,2014).

Parsons has studied "construction quality control/quality assurance plan" in that Materials qualification testing will be done prior to construction to verify that the materials comply with requirements of the specifications. The contractor will obtain representative samples of the materials designated as the proposed source of the materials. Test samples will be sent by the contractor to the Testing Laboratory. The Testing Laboratory will report all test results for determination of material meeting the acceptance criteria. For soils, sampling and analysis will be performed by the contractor on the onsite borrow material source.

The CQAO (Construction Quality Assurance Officer) or designee will periodically inspect material being used. If determined that the characteristics of the material being used differ from the material initially tested, the CQAO designees will direct the contractor to repeat the qualification testing. If the new material qualification test results meet the criteria of the

technical specification as determined by the Engineer of Record, the new materials may be used for the work; otherwise, previously approved materials must be used or other acceptable materials must be sampled and tested as noted above prior to incorporating into the work. The method that was used includes Inspection, Control charts, Pareto diagrams, Statistical sampling, flowcharting, Trend analysis and the result was Quality improvement, Acceptance decisions, rework, Completed checklist and Process adjustment.

On study made on quality control by Agabadudu et al, 2014 the experimental method were used and the test results obtained from experiments conducted on sampled materials of concrete were subjected to further test with the use of SPSS 17.0 software package to validate the postulation that dependence on compressive strength and mix ratio as only parameters in the production of good quality site in-situ concrete is inadequate‘. The statistical tests conducted utilized the ANOVA, Paired T-Test and Chi-square as well as Quality Control Chart tools to test the laboratory results obtained on washed and unwashed aggregate concrete materials. This is the inductive process of drawing a sample from the population in order to ascertain or test whether the assertion or statement about the population could be upheld or disproved by the upheld sample data (Agabadudu et al, 2014). Generally most countries of the world now place emphasizes on the quality of products or services they provide with the use of established quality standards that are in place. When I come to my paper the method that I use will give better solution.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter discusses the research design and methodology used in acquiring the necessary information to achieve the research objectives. It specifically presents the research design, describes research approach and techniques, presents sampling techniques in terms of sample size and selection, validity and reliability of the research, data collection methods and data analysis methods.

3.2. RESEARCH DESIGN AND APPROACH

The research used both experimental and descriptive survey research design and also applied both quantitative and qualitative research approach. The research aimed to evaluate the quality of concrete making materials used currently under construction and investigated the concrete quality control procedures in AAHCPO a case study at which is located at Koye Fech construction site only 20/80 housing scheme was incorporated in this study.

3.3. DEMOGRAPHY

Fig 3.1. Location of Koye Fetch source (Goggle Map data source @2018 goggle)

3.3.1. Data source

This study was used both primary and secondary data sources. The primary data sources were collected from contractors, consultants and clients using different methods such as structured questionnaires, observation and interview with experts. Secondary sources of data were obtained from desk study and previous concrete test results during the period between 2014-2018 years. Moreover, different published books, internet websites, journals and previous research papers. Published books, journals, and articles were reviewed to review related theoretical and empirical literatures. Journals and research papers were used as a base for conducting this study to attempt adding some new finding on the existing knowledge. Internet web sites were the source of unpublished books, journals, and research papers were the major sources of information related to the subject area.

3.4. POPULATION, SAMPLE SIZE AND SAMPLING TECHNIQUES

3.4.1. Target Population of the Study

According data obtained from AAHCPO construction department as of December 2017 there were 107 different grade level contractors and 2 consulting firms which have 44 engineer staff particularly under Akaki Kaliti Housing Construction Project Branch office at Koye fech construction site. Since the project the title focuses on 20/80 housing units therefore, koye fetch was selected in order to be within the scope of study. Based on this the research was purposively selected the construction site because of suitability to research objective and it is on the way to finalize the construction site in this year and the research assumed to get sufficient primary and secondary data sources. Based on these reasons the study targeted on site engineers, resident engineers, project coordinators of consultants, contractors and client's staff.

Therefore, the target populations of this study were a total of 107 contractor firms, 2consultant firms (30 site engineers, 10 resident engineers, 2 project coordinators and 2 production site engineers) which had 44 different engineers and 8 client engineers were participated in this study. Overall the target populations of this study were 159 employees of contractors, consultants and clients which are working in Akaki Kaliti Project Branch office at Koye fech construction site.

3.4.2. Sampling Technique

Stratified random sampling is useful method for data collection if the population is heterogeneous (includes engineers, store keepers, secretaries, guards etc.) In this method, the entire heterogeneous population is divided in to a number of homogeneous groups, usually known as Strata,(site engineers, resident engineers, project coordinators, construction engineers and contractors) each of these groups are homogeneous within themselves, and then units are sampled at random from each of these stratums. The sample size in each stratum varies according to the relative importance of the stratum in the population. Sampling will then be conducted separately in each stratum (Singh and Masuku, 2014). Therefore, this research was used purposive, stratified and random sampling technique to select the appropriate sample size among the target population of the study.

3.4.3. Sample Size Determination

According to data obtained from the AAHCPO as of December, 2017, there are 44 consultant engineers, 8 client engineers and 107 contractor organizations. This study was target only one person from the 107 contractor companies (i.e. owner, project manager or Forman). Thus the sample size can be calculated at 95% confidence level based on the formula from proposed by Assaf et al (2001), p:43) as follows:

$$\textbf{Sample size} = \eta = \frac{n'}{\left[1 + \left(\frac{n'}{N}\right)\right]}$$

$$n' = \frac{S^2}{V^2} = \frac{(0.5)^2}{(0.05)^2} = \frac{0.25}{0.0025} = 100$$

Where,

η = sample size

n' = sample size from infinite population = S^2/V^2

N = total estimated population;

The V = standard error of the sampling distribution = 0.05,

S^2 is the variance of the population elements and V is a standard error of sampling population. (Usually S = 0.5 and V = 0.05). Hence,

- The sample size for 107 contractors,

$$\eta = \frac{100}{[1+[100/107]]} = 52 \text{ Contactors one person from each company}$$

This means that the questionnaire, interciews, observations and test results of the above number of contractors should be distributed in order to achieve 95% confidence level

- The sample size for 44 consultant staff,

$$\eta = \frac{100}{[1+[100/44]]} = 30 \text{ Consultant engineers from two organizations}$$

- The sample size for 8 client engineers

$$\eta = \frac{100}{[1+[100/8]]} = 8 \text{ Client's engineers}$$

Therefore, according to the above calculation a total of 90 questionnaires were distributed to collect relevant data with regard to the research purpose from different engineers of consultants, contractors and clients in AAHCPO under Akaki Kaliti Construction Branch project office in Addis Ababa. The reason that questionnaire used was the respondents were asked first in order to participate in interviewing but most of them were un able to agree with the question therefore it was more focused on questionnaire additionally observation, interview were used.

3.5. DATA COLLECTION INSTRUMENTS/ TOOLS

The study was started by assessing different literatures that related to the study area. The literature review acquired different data from journals, researches that had been made on related topics, books, etc. Various standard codes for concrete quality control such as Ethiopian Building code of standards (EBCS), American Concrete institutes (ACI) codes, American Society Testing Materials (ASTM) were reviewed.

Desk study on selected projects was applied to assess the current concrete production practice in AAHCPO at Koye Fech construction site. The study was collected sample concrete test result which were carried out between from the year 2014-2018 and was compared and analyzed based on Ethiopian Building code of standards (EBCS). In addition, the researcher was collected some samples or specimens which were cured in different period.

To answer specific objectives, the study needed distributed structure questionnaires for contractors, employee's consultants and clients (AAHCPO). Based on literature review,

observation and desk study, well organized closed interview questionnaires were prepared and asked those experts who are currently working in Addis Ababa Housing Construction projects at Akaki Kaliti Project Office.

3.6. MEASUREMENT OF THE DATA

The questionnaires were analyzed based on Likert scale of five ordinal measures regarding determinant factors of quality control of concrete material in the AAHCPO. The questionnaires were rated using a number scale from 1-5.The numbers indicate the degree of agreement of each variables (items) of the respondents to each of the specific questions. The degree of agreements or disagreements of the respondents are outlined as follows.

1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree and 5= Strongly Agree. The main reason of selecting this simple scale is first, to make the respondent feel comfortable and simple in answering those questions and second, for easy evaluation of the collected answers.

3.7. DATA ANALYSIS AND PRESENTATION

The study employed both qualitative and quantitative data analysis techniques. The data obtained from primary sources such as from consultants, contractors and client staff were analyzed and interpreted by using Statistical Package for Social Science (SPSS) version 22. After the data were encoded in to SPSS descriptive statistics like frequency, percentage, mean and standard deviation were analyzed like demographic characteristics of respondents and determinant factors of quality of concrete material in the AAHCPO at Akaki Kaliti Construction Project office. To interpret the test results that were collected from the two consulting were analyzed with Mat Lab software. The data obtained from primary and secondary sources were presented through tables, charts, figures and texts. In addition, based on the data gathered from the informants, appropriate assessment was made.

3.8 VALIDITY AND RELIABILITY TEST

It is important to examine the reliability and validity of the research questionnaires.

3.8.1. Validity

Ensuring validity of different studies made on, interviewing and observation in behavioral research is very important but it is a complicated and challenging exercise. Measuring and evaluating the questionnaire consider some specifications for measuring tools, such as the validity of questionnaire (Julie, 2005). The validity of a measuring tool means that it can measure the relevant specification not any other variable. Content validity was used for measuring the validity of the questionnaires of this research. For this purpose, the content of the questionnaire was prepared by referring to scientific texts, theories and the model relevant to the subject and the questions of the research. After doing amendments by advisor the content validity and face, validity of the questionnaire was approved.

3.8.2. Reliability Test

Reliability refers to degree to which the scores are free from random measurement error (Kline, 2005) and can be examined through assessing the degree of consistency between multiple measures of variables. It also refers to a condition in which similar results was achieved when an instrument designed for measuring variable is used in different places or at different time under similar conditions (Kline, 2005). The reliability of the questionnaires was statistically calculated using Cronbach's Alpha.

The result depicted that Chronbach's Alpha ranges from .709 up to .896 for the each category questionnaire, that means the questionnaire have good reliability. If Chronbach's Alpha result is below than 0.7 the questionnaire should be rejected (Mohsen, 2004). Thereby, it can be said that it is proved that the questionnaire is valid, reliable, and ready for distribution for the population sample.

Table 3.1 Cronbach's alpha test result from SPSS for each category questionnaires

Items category	Cronbach's Alpha	No. of Items
For cement, (coarse, fine) aggregate and Water	0.808	11
Concrete material mixing	0.850	6
Concrete material transport	0.771	3
Concrete material placing	0.714	4
Concrete curing	0.723	3
Concrete testing	0.763	3
Workmanship	0.709	4

Source: Survey result, 2018

3.9 Ethical consideration

The informed consent of all participants was obtained before starting the study. Respondents were given a clear explanation about the nature of the study. In addition participants are informed about data collecting procedure and techniques. The anonymity of the subjects is protected and guaranteed by preventing to write their names and providing clear instruction. Furthermore, the information obtained thorough the questionnaire is only used for the research purpose and the confidentiality is maintained. Therefore, any information obtained from the survey was treated with strict confidentiality.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

The research uses different techniques to analyze the data as follows:

1. The research uses descriptive statistics (frequency and percentage) to describe and analyze the demographic and general information of the research

2. Secondly, the study uses descriptive statistics (mean and standard deviation) to describe the opinion of the respondents on different variables related to quality control concrete practice and procedures in AAHCPO.

4.1 Response rate

For the success of the thesis one of the most valuable thing that was used in order to see the response of respondents were detail questionnaires were designed and distributed for the assessment of concrete quality control in construction of condominium houses in the Addis Ababa Housing Construction Project Office (AAHCPO) in the case of Akaki Kality Construction project branch office at Koye fech construction site. From the wildness of the project office monitors it would be difficult to make interview or any means of collection of information in order to strengthen the investigation. For this purpose a total of 90 questionnaires were distributed to Contractors, Consultants and clients and returned 83 questionnaires with a 92.22% response rate. Table 4.1 shows the summary of number and percentage of questionnaires distributed and returned; and response rate.

Table 4.1 Percentage of questionnaires distributed and returned and response rate

No.	**Respondent**	**Questionnaire distributed**		**Questionnaire Returned**		Response Rate **(%)**
		No.	**(%)**	**No.**	**(%)**	
1	Contractors	52	57.78	46	55.42	88.46
2	Consultants	30	33.33	29	34.94	96.67
3	Clients	8	8.89	8	9.64	100.00
	Total	90	100	83	100	92.22

4.2 Demographic/ General information of respondents

4.2.1 Type of organization of the respondent

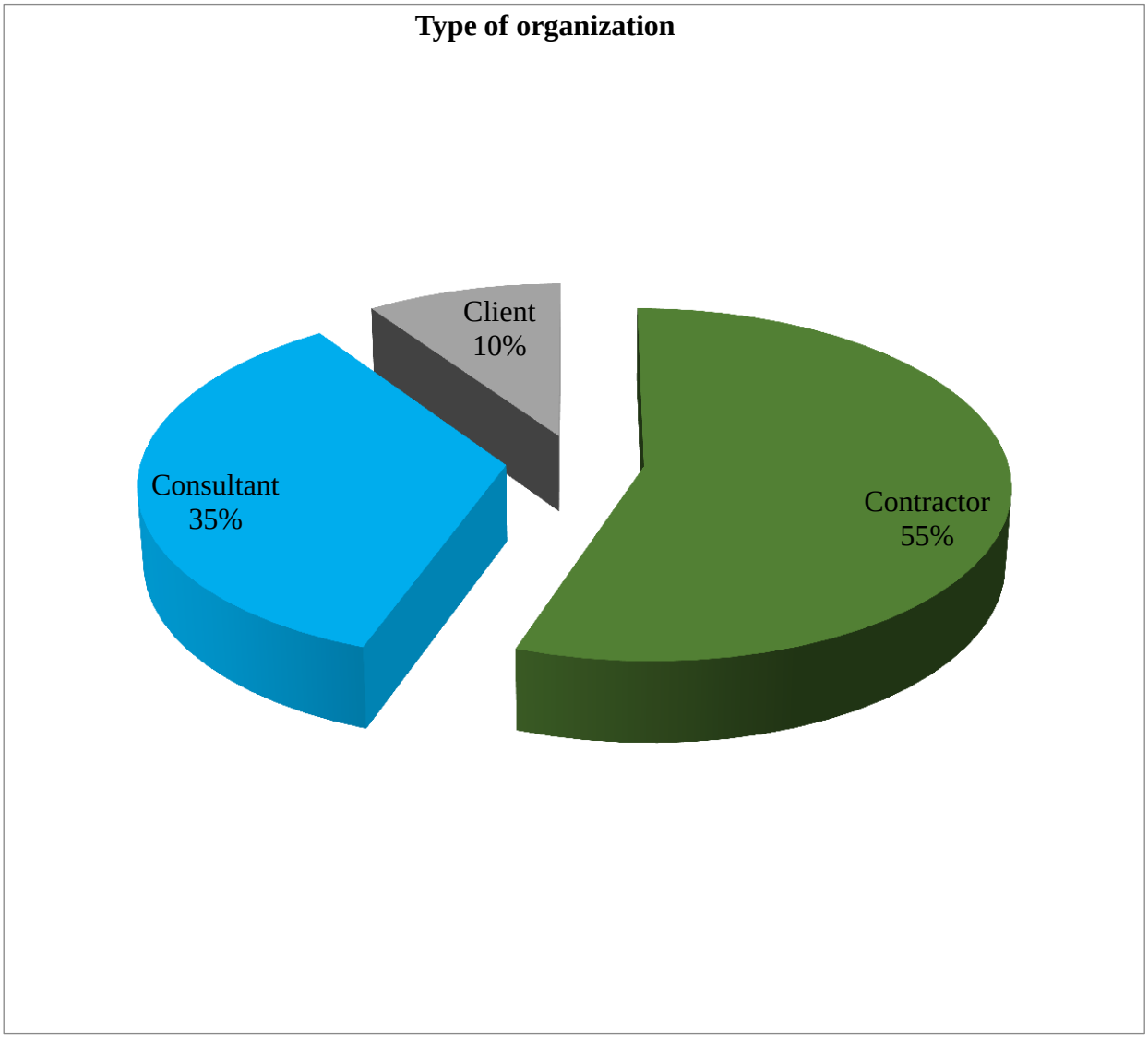


Figure 4.1 frequency and percent of type of organization of the respondent

The above figure shows that the total respondents, 46(55.4%) of respondents were contractors, 29 (34.9%) of respondents were consultants and the remaining 8 (9.6%) of respondents were client employees. The result indicated that the majority of respondents are contractors.

4.2.2 Respondent's position in the organization/company

Table 4.2 frequency and percent of job position of the respondent

	Frequency	Percent
General manager	22	26.5
Project manager	8	9.6
Site Engineer/Supervisor	39	47.0
Resident Engineer	10	12.0
project coordinators	2	2.4
Production site engineers	2	2.4
Total	83	100.0

Table 4.2 result showed that out of the total respondents 22(26.5%) of respondents were working as general manager, 8(9.6%) of respondents were working as project manager, 39 (47%) of respondents were working as site engineer, 10(12%) of respondents were working as resident engineer, 2(2.4%) and in the same way 2(2.4%) of respondents were working as production engineers of contractors, consultants and clients in under Akaki Kaliti construction project branch office at koye fetch construction site in Addis Ababa. The result indicated that the majority of respondents are site engineers/supervisor and general managers out of the total respondents which constitute 73% of the total respondents.

4.2.3 The number of year respondents has experienced in construction industry

Table 4.3 frequency and percentage of work experience of respondents

items	Frequency	Percent
<5 years	38	45.8
5-10 years	23	27.7
11-15 years	15	18.1
>15 years	7	8.4
Total	83	100.0

Table 4.3 illustrates the frequency and percentage distribution of work experience in construction sector of the respondents of this research. Out of the total respondents 38(45.8%) of respondents work experience were falls less than 5 years, 23(27.7%) of respondents work experience were falls between 5-10 years, 15(18.1%) of respondents work experience were falls between 11-15 years and only 7(8.4%) of respondents work experience were falls over 15 years. This implies that out of the total respondents above 73% of respondent work experiences fall below 10 years and this indicating the majority of respondents are young and relatively may lack sufficient experience in construction sectors.

4.2.4 The number of housing construction project that involved by respondent

Table 4.4 Frequency of and percent respondents involved in housing construction project

Number of projects	Frequency	Percent
1 project	34	41.0
2 project	24	28.9
3 project	20	24.1
4 project	5	6.0
Total number of projects	83	100.0

Table 4.4 result indicated that out of the total respondents involved in this survey 34(41%) of the respondents were involved in only one housing construction project, 24(28.9%) of respondents were involved in two housing projects, 20(24%) of respondents were involved in three housing construction projects and only 5(6%) of the respondents were involved in four housing construction projects. This implies the majority of the respondents are only involved in one housing construction project. This may have a problem related to quality of construction quality due to lack of sufficient experience in construction sector. This result may be associated with table 4.3 or work experience of the respondents in construction sector.

4.2.5 The highest level of education you have completed

Table 4.5 Frequency and percent that the field of study of respondents

	Frequency	Percent
TVET Certificate	2	2.4
College Diploma	14	16.9
University Degree	59	71.1
MSC/MA	8	9.6
Total	83	100.0

Table 4.5 result indicated that out of the total respondents only 2(2.4%) of the respondents education qualification were TVET certificate, 14 (16.9%) of respondents educational background were college diploma, 59(71.1%) of respondents educational background were university degree and the remaining 8(9.6%) respondent's educational background are master's degree. The result indicated that the majority of respondent's educational background is university degree which constitute above 70%out of the total respondents. This is an opportunities to construction project of the condominium houses.

4.3 Descriptive Analysis of the respondents

The following descriptive analysis were carried out to know related to quality control procedures and cause to produce low quality concrete material in Akaki Kaliti Housing project Branch office at Koye fech. Respondents were ranked from 1-5 scale each statement according to the severity and agreement of the problem in the study area.

4.3.1 Cement, (coarse, fine) aggregate and Water

Table 4.6 Mean and standard deviation of respondents toward each statement

Cement, (coarse, fine) aggregate and Water	N	Mean	Std. Deviation
Contractor view	83	2.24	1.122
The quality of pasca/water tanker/ that is used for storage of water questionable/has dirty substance in it.	83	3.24	1.111
The aggregate are stored properly in self-draining form/like in hogging form /	83	2.69	1.109
The grading size of coarse aggregate fulfills the specification by visual inspection.	83	2.87	1.068
Rain water will be used for concrete production or curing purpose in the cases of have no water on site.	83	3.52	1.063
The quality of sand that is provided by contractor is free from organic impurities with low silt content.	83	2.32	1.059
Applying cement on to water tanker is one means of treatment.	83	3.87	1.057
The quality of coarse aggregate fulfills the required specification such as hardness, free from materials that likely to be decomposes and does not show change in volume when exposed to weather.	83	3.27	1.013
Jar test will be done to know the level of silt content.	83	3.12	1.004
Client point of view	83	3.58	0.926
The type of water that is used for mixing concrete is potable/drinkable/	83	4.46	0.901
There is a mechanism that is used to control the quality of ingredients for concrete production on project site such as cement, sand, coarse aggregate and water	83	3.25	0.876
Valid N (list wise)	83		

Table 4.6 result illustrated that related to cement, (coarse, fine) aggregate and water each statement were ranked according to the respondents level of agreement by using mean score value and standard deviation. For the statement there is a mechanism to control the quality of ingredients for concrete production on project site such as cement, sand, coarse aggregate and water scored a mean value 3.25 and standard deviation (SD) value 0.876. This indicated that the majority of respondents ranked neutral and slightly. Where N refers to the number of respondents.

Few respondents given above neutral point related to the quality of sand that is provided by contractor is free from organic impurities with low silt content scored a mean value 2.32 and SD value 1.059. This result shows the sand delivered by contractor is not free from organic substances and it has effect on the quality of concrete production. That means the contractors are delivering less quality sands for concrete production. Related to the statement the cement bag is placed on timber platform in order to protect it from moisture and cement which comes first will be used first on client point of view scored a mean value 3.58 and SD value 0.926 and on contractors point view scored a mean value 2.24 and SD value 1.122. This implies that the contractors are not placing cement bag on timber platform in order to protect it from moisture and they are not using cements according their first in first out methods. This may affect the quality and strength requirement of cement.

Related to the statement the quality of coarse aggregate fulfills the required specification such as hardness, free from materials that likely to be decomposes and does not show change in volume when exposed to weather all respondents on average scored a mean value 3.27 and SD value 1.013. Regarding this statement like others statement, the majority of respondents were neutral and a few of the respondents agree. This means respondents were not clear whether the coarse aggregate fulfills the required specification or not when exposed to weather.

The aggregate are stored properly in self-draining form/like in triangular distribution form/hogging on average all respondents scored a mean value 2.69 and SD value 1.109. The result indicated that on the average all respondents scored between disagree and neutral to this statement. That means the project office is not storing properly the aggregate in hogging form and this will enable the aggregate to absorb moisture. This will have effect on the quality of concrete production. For the statement the grading size of coarse aggregate fulfills the

specification by visual inspection on average all respondents scored a mean value 2.87 with SD value 1.068. This indicated also the majority of respondents agreed below neutral and above disagreement. That means the grading size of coarse aggregate does not fulfills the specification to the required level.

The type of water that is used for mixing concrete is potable or drinkable on average all respondents ranked a mean value 4.46 and SD value 0.901. The result indicated all most all agreed and strongly agreed which means the project is using quality water. However, during the researchers site visit some contractors were not using the water which was stayed for longer time in the containers with dust materials and with organic substances. Even some containers are open for long time and dust and every unnecessary material were entered in it. If the contractor used unclear water it will affect the quality of concrete. The quality of *pasca* /container that is used to store water/ that is used for storage of water questionable or has dirty substance in it scored on average a mean value 3.24 and SD value 1.111. This implies the majority of respondents scored above the neutral value and it shows relatively the quality of *pasca*/water tanker/ is containing organic substances as previously discussed it. This will have also effect on the quality of concrete production.

Applying cement in to water tanker is one means of treatment scored a mean value 3.87 and SD value 1.057. This one means the contractors use to treat the water. On this statement on average the majority agree the contractors are using cement to treat unclear water. Rain water will be used for concrete production or curing purpose in the cases of absence of no water on site on average all respondents scored a mean value 3.52 and SD value 1.063. This result indicated that in absence of potable water is used for mixing of concrete materials. This is one means to minimize shortage of water on construction site. This is a good mechanism to solve the problem. Finally the organization use Jar to test to know the level of silt content scored a mean value 3.12 and SD value 1.004. These results also agree with the first statement there is a mechanism to control quality of concrete ingredients. On this on average all respondents have similar understanding and AAHCPO is using inefficient quality concrete production mechanisms.

4.3.2 Descriptive statistics for concrete material mixing

Table 4.7 Descriptive Statistics for concrete material mixing in AAHCPO

Items	N	Mean	Std. Deviation
There is mechanism to check the required workability by using slump/cone test	83	1.73	0.700
There is mechanism of proportion of water cement ratio for production of concrete.	83	1.99	0.834
The box size of aggregates that is used forC-25 (25MPa) with 1:2:3 compressive strength concrete is 40*50*18.	83	4.11	0.797
The procedures that commonly used for mixing concrete in bathing plant is with box size of 40*50*18water (2coarse +1 sand) aggregate cement (1coarse+1 sand)aggregate water.	83	3.84	0.956
The mixing time has an effect on concrete strength and quality.	83	4.52	0.669
Due to the increase in volume of sand(bulking) due to absorption of moisture will affect the total volume of concrete.	83	4.20	0.880
Valid N (list wise)	83		

Table 4.7 results indicate the second category which constitutes six items and the SPSS result is presented as follow. For the statement there is mechanism to check the required workability by using slump or cone test on average all respondents scored a mean value 1.73 and SD value 0.700. This result indicated that the all most all respondents strongly disagree with this statement and the project does not use a mechanism slump or cone test. Unable to use such checking of workability significantly will affect and lead to rework construction. The statement there is mechanism of proportion of water cement ratio for production of concrete scored a mean value 1.99 and SD value equal to 0.834. Like the first statement all most all respondents disagree with the statement and showing there is no appropriate mechanism of water cement proportion

measurement on the site. This is also a major problem to produce quality concrete on the construction site. Absence of such appropriate mechanism of water cement ratio will effect on concrete quality as it is stated above. Slump test is used extensively in site work all over the world .the slump test does not measure the workability of concrete, although it as a measure of consistency. But the test is very useful in detecting variation in the uniformity of a mix of a given nominal properties (Neville 2000).

The box size of aggregates that is used for C-25 (25MPa) with 1:2:3 compressive strength concrete is 40*50*18 scored a mean value 4.00 and SD value 0.797. This indicated that all most all on average all respondents agreed the project is using the appropriate and standard box size. This also an important element to produce quality concrete and it will enable to produce the desired concrete quality at production site. Similarly for the statement procedures that commonly used for mixing concrete in bathing plant is with box size of 40*50*18water (2 coarse +1 sand) aggregate cement (1coarse+1 sand) aggregate water scored a mean value 3.84 and SD value .956. On this statement almost all agree the construction project use box size of 40*50*18 water (2 coarse +1 sand) aggregate cement (1coarse+1 sand) aggregate water. This is also an important element to produce quality concrete product.

The mixing time has an effect on concrete strength and quality scored a mean value 4.52 and SD value 0.669. This implies that the mixing time has significant effect on the quality of the concrete production and on this statement on average all respondents agree the project office is keeping the mixing time. Like the above statement the moisture absorption of sand will increase the total volume of concrete scored a mean value 4.20 and SD value equal to 0.880. The result indicated that there the sand is absorbing moisture at the construction site of Koye Fech. This implies that due to absorption of moisture by sand will cause to increase the volume of concrete and this may lead to decrease the strength of the concrete at production site.

4.3.3 Descriptive analysis of concrete material transport

Concrete is a mixture of water, cement, aggregate and admixture. After mixing, operation such as transporting, placing , compacting and finishing of fresh concrete can all considerably affect the properties of harden concrete.

It is important that the constituents materials remain uniformly distributed within the concrete mass during the various stages of its handling and that full compaction is achieved (Jackson, 1980).

Table 4.8 Descriptive Statistics for concrete material transport in AAHCPO

	N	Mean	Std. Deviation
Wheel barrow and barella (flat open pan constructed from iron sheet) is used for transporting and place on position concrete	83	4.05	0.516
The above transporting materials have an effect on segregation(separation of each ingredients from one another)	83	3.77	0.888
For vertical transportation winch is used	83	3.98	0.725
Valid N (list wise)	83		

Table 4.8 descriptive analysis result indicated that the statement for transportation of concrete material the project is using wheel barrow and *barella* (flat open pan constructed from iron sheet) ranked a mean value 4.05 and SD value 0.516. This result revealed that the majority of respondents agreed with the statement and the construction site used wheel barrow and *barella* to transport fresh concrete on the site. Related to transporting materials have an effect on segregation (separation of each ingredients from one another) the respondents ranked a mean value 3.77 and SD value 0.888. This implies the respondents almost nearer to agreement using wheel barrow and *barella* has effect on the segregation of concrete material. This indicates using the appropriate transportation mechanism is important to minimize effect segregation. The third item in this category is the use of winch. On this item the respondents were scored a mean value 3.98 and SD value 0.725. This implies the majority of contractors are using a vertical transportation winch to transport concrete materials. This will improve the construction time and transportation facility and minimize the segregation of concrete material. Therefore, from respondent's feedback it was advisable to use winch as the height floors increased.

4.3.4 Descriptive analysis concrete making material placing mixing

Table 4.9 Descriptive Statistics concrete material placing in AAHCPO

Items	N	Mean	Std. Deviation
Vibrator is used for compacting purpose	83	4.07	0.838
Over and under vibration has an effect on segregation.	83	4.18	1.095
The height of placing concrete on to form has an effect.	83	4.13	1.079
Reserved vibrator is found on site.	83	2.34	1.142
Valid N (list wise)	83		

Table 4.10 result depicted that the statement to compact contractors are using vibrator scored a mean value 4.07 and SD 0.838. This indicated that almost all respondents are agreed the contractors are using vibrator to compact the concrete. Using vibrator is an important element to improve the quality of concrete and enhance its strength. However, sometimes some contractors were using reinforcement bar to compact concrete, this will affect especially public buildings and it may affect the overall quality of strength of the construction.

The second item under this category is use of over and under vibration has an effect on segregation scored a mean value 4.18 and SD value equal to 1.095. This implies in construction of concrete material at Akakai Kality Housing construction project there is over and under vibration while compacting the concrete. Applying over and under the optimum rage significantly reduce the strength of the concrete. Therefore, it is advisable to apply the optimum range of vibration while compacting the concrete to improve the quality of the material.

The third item is the height of placing concrete on to form has an effect scored a mean value 4.13 and SD value 1.079. This indicated that while placing concrete on to formwork using appropriate is very important and almost all respondents are agreed on this item. Sometimes some works may not use the appropriate height to place the concrete material and this may affect the quality of the concrete. The last item under this category is having reserve vibrator on site is scored a mean value 2.34 and SD value 1.142. This implies the majority of respondents disagreed with the statement and indicating the majority of respondents do not have additional

vibratory on construction site. It is good if contractors have additional vibrator on construction site to avoid the performance of the construction project if incase fail the vibrator.

4.3.4 Descriptive Statistics concrete curing

Table 4.10 Descriptive Statistics of concrete curing in AAHCPO

	N	Mean	Std. Deviation
The project keeps the appropriate time of curing for casted concrete and has effect	83	2.20	1.007
Water spraying or covering sheets for period of curing for casted concrete is used	83	1.72	0.739
The date of curing casted concrete is minimum of seven days	83	1.87	0.869
Valid N (list wise)	83		

Table 4.11 result indicated that the descriptive analysis of concrete material curing in AAHCPO. The project keeps the appropriate time of curing for casted concrete and has effect scored a mean value 2.20 and SD value 1.007. This indicated that the majority of respondents are disagreeing with the statement. This implies the project is not keeps the appropriate curing time while casting the concrete. If contractors do not use the appropriate curing time it will highly affect the quality of the concrete.

The second item in concrete curing water spraying or covering sheets for period of curing for casted concrete is used scored a mean value 1.72 and 0.739. This implies the majority of respondents are strongly disagreeing with the statement. This shows the project is not using water spray or covering sheets while producing concrete materials. If the project use water spray or cover sheets it will improve the quality of concrete material. The third item, the date of curing casted concrete for minimum of seven days scored a mean value 1.87 and SD value 0.869. Like other items, on this item on average all respondents are also disagreed which means the project is not keeps the curing time.

4.3.5 Descriptive Statistics concrete testing

Table 4.11 Descriptive Statistics of concrete testing in AAHCPO

	N	Mean	Std. Deviation
Sample concrete cube test taken for given executed work is at the end of casting and special care is made for the sample.	83	4.37	0.587
Rebar with diameter #16 is used for compaction purpose therefore its length has compacting effect in preparing concrete cube sample with size of 15*15*15cm.	83	4.31	0.544
For sample to be crushed for 7th or 28th day if the sample fails the so called hammer test will be order by consultant.	83	2.39	0.946
Valid N (list wise)	83		

Table 4.12 result indicated that sample concrete cube test taken for given executed work is at the end of casting and special care is made for the sample scored a mean value 4.37 and SD value 0.587. This result shows at production site special care is taken for concrete testing. This a very dangerous practices because the test results always show positive and mislead the decision makers. Therefore, it is advisable to take sample concretes randomly from the site the site and based on this the project should take an action.

The second item under this category is Rebar with diameter #16 is used for compaction purpose therefore its length has compacting effect in preparing concrete cube sample with size of 15*15*15cm scored a mean value 4.31 and SD value 0.544. The result indicated the majority of respondents are agreeing with the statement. This show at the construction site 16mm diameters was used for compaction purpose and this may have effect on quality of concrete. The third item for sample to be crushed for 7th or 28th day if the sample fails the so called hammer test will be order by consultant scored a mean value 2.39 and SD value 0.946.

4.3.6 Descriptive Statistics workmanship

The quality of concrete is affected by its constituent materials, the equipment used and the workmanship in concrete production process. A better or poor concrete may be made of exactly the same ingredients based on the quality control practice of the production process. Lack of attentive control on each production process, lack of management commitment and poor workmanship in quality concrete production is also the most frequent problems identified by respondents (Neville, 2010).

Table 4.12 Descriptive Statistics of workmanship in AAHCPO

	N	Mean	Std. Deviation
Consultants have sufficient work experience and knowledge related to quality control	83	2.80	0.732
Contractors have got appropriate awareness and training on quality concrete production process	83	2.29	0.849
The micro small enterprises have sufficient quality concrete production experience and knowledge of precast beam	83	2.42	0.683
Valid N (list wise)	83		

Table 4.13 result illustrates the workmanship related items of respondents in AAHCPO in AKaki Kaliti branch project office at Koye Fech construction site. Under this category consultants have sufficient work experience and knowledge related to quality control scored a mean value 2.80 and SD value 0.732. This indicated that the majority of respondents agree between disagree and neutral level. This means the majority of consultant employees may not have sufficient work experience in the construction project. This result also agrees with the demographic part table 4.3 and table 4.4. These tables show the majority of employees work experience is below 5 years and they involved in one housing project throughout their work experience. If the employees lack sufficient work experience they may not be able to control the quality of concrete.

The second item contractors have got appropriate awareness and training on quality concrete production process scored a mean value 2.29 and SD value 0.849. Similarly like the first item on

this item almost the majority of respondents are disagreeing. These shows the contractors are not getting full awareness and training related to quality concrete production in AAHCPO at Koye Fech site. If contractors do not get sufficient awareness and training related to concrete production it may affect the overall construction project. It is important to train and create awareness to contractor's staff as well as to those involved in the construction site to improve the quality of concrete.

The final item, the MSEs have sufficient production experience of quality precast beam scored a mean value 2.42 and SD value 0.683. This also like the others the majority of respondents scored between disagree and neutral. This shows the MSEs do not have sufficient production experience and this will able to affect the production of quality concrete. If the project closely trains and closely monitors the performance of MSEs the quality of concrete will increase and they will get sufficient work experience.

The current practice implemented in Addis Ababa Housing Development Project Office (AAHDPO) in the case of Akakai Kality Housing Branch Office as compare to Ethiopia Code of Standard (EBCS2 of 1995) is discusses in this chapter. According to EBCS 2, on chapter 8 of specification and workmanship provides minimum specification requirements for materials and for the standard of workmanship that must be achieved on site in order to ensure that the design assumptions in this code are valid and hence that the intended levels of safety and of durability will be attained.

According to EBCS means of specifying concrete are in three ways from those lists the important one that is used in Addis Ababa Housing is prescribed mixes with this method, the designer assumes responsibility for designing the mix and stipulates to the producer the mix proportions and the materials which shall be employed.

In order to secure good hardened concrete, certain fundamental principles should be borne in mind in handling when it is fresh. The best concrete mix can be easily damaged when a little mistake is made on the way from the mixing place to the forms. Therefore, each step in handling and transporting should be carefully controlled. Segregation i.e. of coarse aggregate from mortar or of water the other ingredients, should be prevented. The equipment and method of handling and transporting concrete should be selected according to placing conditions.

4.2. Concrete Making Materials Handling

The over all concrete quality is affected by different reasons starting from selection up to testing of concrete. In order to see these desk study, interview with experties, distributing questionarrie to different respondents and test result collected from two consulting firm and sample test made on stie which is under concrete production. Therefore, in preparation of questionarrie it was sub divided into material handling , mixing, transporting, placing, curing, testing and workmanship. The sum of all these things will affect the quality of concrete. What so ever the materials fulfills the required specification the type of workmanship that will affect the over all strength of concrete from beginning of handling to testing. The standard of workmanship throughout the concreting operations is therefore extremely important in construction of a good quality concrete structure.

The need for this study is to see the quality control for concrete materials in Addis Ababa Housing in Akaki Kality project site that includes cement, aggregate (fine and coarse) and water. Therefore, the following discussion had been on the basis of questionarrie, interview with experties ,test result collected and taken directly from site which are under construction. Inorder to see the respondents feed back the following detail discussion is made and comparision is done on the basis of EBCS 2 1995 and ESCP.

4.2.1. Portland Cement

Observation and feed back from respondents shows that, the type of cement that is used in koye fetch site are:

- Ordinary Portland Cement (OPC) such as dangote, derba, mesobo,muger,east cement etc.
- Pozollana portland cement (PPC) such as national cement.

The cement content to produce $1m^3$ of concrete is $360kg/m^3$ found from contract document. And the grade of concrete is class I, according to ES1177-1:2005 there are 27 distinict cements grouped in to 5 cement types and 6 strength class, from the cement types OPC and PPC are used in AAHPBO in the case of Akaki Kality construction site and from the six strength classes 42.5R, 42.5N,32.5R and 32.5N hence R and N are stands for high early strength and ordinary early strength. The strength classes that is labled on the bag of PPC cement is 32.5R/Nand OPC 42.5R/42.5N according to *ISO900620*- International quality

management certification *ES EN-197-1-2013*- National standards (Dr Ephrem S.,2014) in order to produce C-25 concrete.

Based on the feed back that is shown from the respondents the placement of cement bag had not got an attention from the three parties since the cement bag is did not laid on plat form the observer also seen that most of the contractors are more focuse on casting concrete or doing their work and the moisture that the bag exposed had no effect on the strength.

Fig.4.2. Client Store

The principle of first in first out is applied on the client side is applied in some extent that means there are two door opening that one door is used for the entrance of cement and the other one is for exit purpose but the orientation of the cement bag is in circular fashion and there is no platform for that is used to lay the bag of cement. What ever happens they have no means of checking the age of bag may be for cement bag that absorbs moisture will be harden so that they will throw it out other wise it will be used for different purpose. When we come to contractors store there was only one door that is used for entrance and exiting of cement bag in the observation that the study saw some of the contractors had tried to place the cement bag on to timber plat form. But they had no any means of checking the age of cement bag if and only if it shows sign of hardening.in contractor point of view since cement, aggregate and water are provided by client and this ingridients are not tested on site it meant that they had fulfilled the required specification as per Ethiopia Code of Standard. When the research compares to the actual situation with EBCS it is stated that cement shall be stored in a clean container and protected from moisture both in transient and during storage.(EBCS 2,1995 Handling and Storage of the Materials).

Fig 4.3. Contractor Store

4.2.2. Aggregate

In relation to aggregate the respondents and experts agreed up on the tests that had made on especially on presence of poures materials flakiness and elongation index are not that much trusty because most of the aggregate materials found on the site shows the defect and the size of aggregate was 02 but on the observation made on the site there was 01and 04 that means it would have not fulfill the required specification in relation to strength and finishing effect. And the respondent agreed up on the effect of aggregate to form cold joint and segregation. In addition to these the placing of aggregate had not got that much emphasis especially on client stoke, inorder for the place to hold large quantity of aggregate loader had been used for purpose of place to hold more aggregate that means had no means of draing moisture especially rain water because means of laying the aggregate is not in hogging form. That means the amount of moisture content found on the coarse aggregate can not be known. In the case of aggregate having poures substance in it the content of moisture will be exagurate. But there is no mechanism that is found to check the moisture content in it. When the researcher compares the experties and respondent feed back with EBCS it was stated that Aggregates shall be handled and stored so as to minimize segregation and contamination with undesirable constituents. Separate storage facilities with adequate provision for drainage shall be provided for each different nominal size of aggregate used. (EBCS 2 1995 8.4.2.2(1) page 95)

Fig 4.4. coarse Aggregate

4.2.3. Fine Aggregate (sand)

This type of aggregate is provided by contractor from the respondents feedback there was no reliable source to get low silt content sand. In addition to this the consultants approval were not made before the sand is damp on site and rejected sand were seen in the site without.

Fig 4.5. Sand

Moisture absorbed sands was damped on site and the reason some of the contractors sprayed water on to the sand while the sand dried out the dusts found in it had blowed.

Because of their small size and weight, sand particles are easily pushed and held apart by surface water there by increasing the total volume per given weight of sand. This phenomenon is known as bulking. (Composition of concrete hand book page 8)

4.2.4 Type of water

Water that is drinkable is suitable for concrete mixing. It has two functions:

i. React chemically with the cement, which will finally set and harden, and
ii. Lubricate all other materials and make the concrete workable.

The total amount of water required per unit volume of fresh concrete depends on the following factors.

1. The desired consistency of the concrete, which may be expressed, as will be seen by the slump or ball penetration test.
2. The maximum size, particle shape and grading of the aggregate.
3. Water reducing or air entraining admixtures.

The type of water according to respondents' feedback it is showed that the type of water that is used is potable or drinkable generally it is agreed that, water which is used for drinking is safe to use in concrete production. The type of drinkable water is provided by client and transported by using truck and distributed to contractors. The problem that was clearlly seen in relation to the water tanker(pasca) that the contractors used there are dirty substance in it. Applying cement on to pasca is means of treatment that they had used inorder to sedment the dirty substances. Basically in rainy season no means of covering the water tanker and no emphasis is given for concrete produced by using rain water. No test is conducted for water that is used for concrete production.

Fig. 4.6. Dirty Water

4.2.5. Concrete Materials Mixing

According to EBCS 2 Quality control consists of two distinct, but interconnected parts, namely production control and compliance control.

- ✓ Production Control: Comprises a combination of actions and decisions taken during production to check the operation and to obtain a reasonable assurance that the specifications will be satisfied.

- ✓ Compliance Control: Comprises a combination of actions and decisions, in accordance with compliance rules adopted in advance, to check the compliance of the product with the specifications.

There fore this sub topic discusses about the production control in which the decision that was made inorder to produce good quality concrete. From the respondents feed back there was no mechanism that is made inorder to check the consistency and workability of mixed concrete.The accuracy of the mix proportions shall be checked regularly. The consistency of the fresh concrete shall be checked periodically with the slump test (EBCS 2 1995 of 9.2.3 Control of Mixing, Transportation and Placement of Concrete sub division (1) page 101).

Fig 4.7. Concrete making materials

There is no means of fixing water cement ratio so that the moisture content found on sand and coarse aggregate not known. From observation made and questionarrie distributed the amount of water that is used for mixing concrete was fixed visualy the mixer operator balance the water by using trial and error method and they had experienced through time on the sufficent amount that is need to produce the required mixed concrete. From observation made most of the workmanships prefer workability than any other thing such as strength. Since most of them were not trained quality control issues and also most of the works are given to sub contractors and their intention is to finish their casting with in a day. In the situation that they intended to finish the work they keeps increasing workability inorder to facilitate the crues involved as the workability increases the compactability of the concrete will increase as the strength decrease.

In order to produce C-25 concrete compressive strength the mixing proportion that the contract document that is refered from Akaki Kality project states 1:2:3 proportion which represents one bag cement (50kg), two boxes of sand and three boxes of coarse aggregates respectively and they usually uses 350 liters diesel mixer. In such case the box size that is used to produce the required compressive strength is 50 (length)*40 (width) *18 (depth). And most of the respondent are agreed up on the size of the box.

The method that is used to mix the ingridient in the batching plant follows the procedure of water $\longrightarrow$(coarse +sand) aggregate $\longrightarrow$ cement $\longrightarrow$ (coarse +sand) aggregate $\longrightarrow$ water. There was no means of controlling the mixing time it was also the decision of the operator to fix the time. And they agreed up on the time of mixing has an impact on strength and quality.

4.3. Concrete Material Transporting, placing and compacting

As the ingridients are mixed on the batch plant the next step will be transporting the mixed concrete to the place where it is casted. From the respondents and observation most of them had used barrella which is flat open pan constructed from iron sheet. In the case of G+7 wheel barrow is used. And the respondent are strongly agreed up on those type of transporting materials have an effect on segregation/ separation of ingridient. On casting of ribbed slab the vertical transporting material i.e winch is used. It is fixed on the required place the second step was placing concrete on to barrella by using shovel. Then transporting the concrete to the casting area. After all this process compacting it. For purpose of compaction vibrator is used but no attention is given for the orientation of poker vibrator and they had no know how whether it has strength related implication. Most of the respondents did not agreed up on the reservation of vibrator in the project site. For the situation of malfunctioning of vibrator they had lended from neighbour contractor.

According EBCS 2 1995 8.4.4 from (1) to (8) page 94

(1) Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods which will prevent the segregation or loss of any of the ingredients and maintain the required workability. It shall be deposited as nearly as practicable in its final position to avoid rehandling. In the case of AKHPBO there are atleast two or three cycle in transportation process.

(2) All placing and compacting shall be carried out under the direct supervision of a competent member of the contractor's (or manufacturer's) staff. Class I concrete of grades C20 and above shall be compacted by using vibrators. Since all contractors are used vibrator but direct supervision and knowledage about how to use the vibrator inorder to reduce segregation and expail of air inside concrete.

(3) Concrete shall be placed soon after mixing and thoroughly compacted during the operation of placing. It shall be thoroughly worked around the reinforcement, tendons or duct formers, around embedded fixtures and into corners of formwork to form a solid mass free from voids. On the observation made currently active site especially on G+7 spacers were casted flat open pan made of mortar inorder to get required concrete cover for structural parts of the building such as beams, columns, stair cases etc.

(4) Care shall be taken to avoid the displacement of reinforcement or movement of formwork and damage to faces of formwork. The so called “kerevat” bracing system that they had used for column height of 2.43 four with out “abay kerachare”.

(5) The depth of lift to be concreted shall be determined by the contractor or the manufacturer in consultation with the engineer. Observation showed that no consideration made depth of lifting concrete.

(6) In order to avoid segregation, the free fall of concrete mass shall be restricted to a maximum of three meters unless the system of placing concrete is approved by the designer.From experties response height of 3m is considered especially column casting.

(7) When vibrators are used to compact the concrete, vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner which does not promote segregation of the ingredients. Most of the respondents are agreed up on the both over and under vibration has an effect but knowledge of presence of air inside the concrete not that much considered.

(8) The mix shall be such that there will not be excess water on the top surface on completion of compaction. Bleeding is defined as the apperance of water on the surface of concrete after it has consolidatesd but before it is set. From the concrete making ingridients water is the lightest component. It is the result of aggregates settling in to the mix and releasing their mixing water. Most of the workmanship prefer workability that means the amount of water content found inside mix is high for that reason paste and water comes on top finished surface.

4.4. Concrete Curing

In order to reduce level of porosity to satisfy level of strength and durability an adequate supply of moisture is necessary (Property of concrete chapter 11 curing page 45). In order to produce more calcium hydrate silicate (C-H-S) gel around cement grain, the casted concrete has to cure regularly The strength of concrete will increase as the age of concrete increase that means more C-H-S gel will be formed. On the questionnaire that was distributed and collected all the respondents had agreed up on date of curing have an effect on concrete compressive strength. From the different types of method of curing there were agreement and dis agreement on water spraying and covering sheet method of curing. These types curing method are for retaining

moisture found inside mixing concrete. On the observation made on the construction site covering sheet not visible. Mostly sprinkling of water is adopted but the degree varies from one contractor to another. Some of the contractors assign the guard by paying salary to cure the casted and plastered concrete. It may or may not be satisfactory to get the desired output. Keeping curing of concrete quality of water did not get attention since the effect efflorescence clearly seen on the finished surface.

Fig 4.8. Buildings exposed to efflorecence

According to the distributed questionnaire the respondents, agreed the real practice of curing is not greater than three days and the others are agreed up on the minimum curing time is

seven days. As number of story increases it is difficult to cure by man power therefore the contractor had used water pump. Shortage of water is too high the hydrant sometimes would fill two or three truck a day from the hugeness of the project there were many contractors complaining the concentration of water to distribute to all contractors in need of water.

Fig 4.9. water for Spraying purpose

According to EBCS 2 1995 8.4.7 Curing

(1) The methods of curing and their duration shall be such that the concrete will have satisfactory durability and strength and the member will suffer a minimum of distortion, be free of excessive efflorescence and will not cause, by its shrinkage, undue cracking in the structure.

Chapter 9.2.4 Control for Curing the Concrete

(1) It must be checked that curing complies with approved method curing depending on the environment and on any special requirements.

4.5. Concrete Sample Testing

One sample test had taken for 114m^3 volume of concrete and from the observation made concrete greater than 114 m^3 were not found on the site this is the implication that sample had taken once per casting. (Ephrem /28/2016).

Fig 4.10. Test smaple and its result

From the respondents feedback for sample that is failed nondestructive test or hammer test did not ordered by consultants in the situation where test failed repetitive sampling had been taken after 7th day of concrete sample was tested. The beneficiaries from this repetitive sampling is no one because the contractor still spent his money, the consultant did not exercise his or her

responsibility and the client trusts the consultant and approved the payment. But sometimes the testing company asks whether consultant was present and if the laboratory technician suspects that the consultant were not experienced the employee of the company has the power to correct the failed test result.

Acceptance and compliance according to Ethiopian standard (EBCS 2, 1995)

The lot could be defined as the quantity of concrete produced in the same essential conditions and subjected to individual assessment. There is a minimum requirement set on the size of lot and frequency of sampling (EBCS-2, 1995) as given here under.

(a) No individual sampling can represent, on the average, more than 100 mixes or 100 m^3.

(b) For each grade of concrete, at least one sample shall be taken every week.

(c) For each grade of concrete, at least two lots shall be made.

Criterion 1: this criterion may be applied in all cases but is less suited to large scale sampling each lot is represented by three samples, the strength of which are: x1< x2 < x3.

The lot is accepted if the following conditions are satisfied simultaneously.

$$m_{3\geq f_{ck}} + k_1 \quad \text{.....4.5a}$$

$$x_{1\geq f_{ck}} - k_2 \quad \text{.....4.5b}$$

Where, $m_3$is the mean value

f_{ck} is the specified characteristic strength, K_1 & K2 are the margins of strength given in the table 4.14 below, X_1 is the average strength of the minimum strengths for the several lots.

Table 4.14. Margin of Strength

Margin of strength	First two lots	Third and fourth	Fifth lot and above
K_1	5	4	3
K_2	1	2	3

Criterion 2:- this is suitable for large lots. Each lot is represented by not less than 15 test specimens and the lot is accepted if the following conditions are satisfied simultaneously.

$m_n - \lambda s_n \geq f_{ck}$ ……...…4.5c

$x \geq f_{ck} - k_2$ ……..…....4.5d

Where, m_n= is mean value

S_n = is standard deviation of set of sample result

f_{ck} = is characteristics cylindrical strength

λ = is coefficient (lamda may be taken 1.4 Mpa)

n = is number of specimens

The lot is accepted automatically if the above equations are simultaneously satisfied. If the test results do not satisfy the requirements of the above acceptance criteria, there are recommended measures to be taken. The measures include:

- Structural safety shall be checked by appropriate calculation.
- Checking the strength by taking drilled cores or by non-destructive methods such as rebound hammer test. However; the results of this test will be affected by surface finish, rigidity, moisture content and direction of impact.

From the test result collected from consultants by 7^{th}, 14^{th}, 28^{th} and 45^{th}. Most of the results fall in margin between $7^{th\ and}$ 28^{th}. A total of 181 results were collected and from those only four results were taken to be fail, but the rests were taken to be fulfill the requirement. The reason to say that the results are fulfilled the requirement since most of the contractors are paid for the

concrete quality test from the approved payment that was attached on summary of individual blocks. From the compliance criteria stated above it has to be checked.

The above two compliance criteria's as stated above, the values of K_1 and K_2 are variable as shown in table 2.14. For this specific analysis of test results, both the values of $K_1$and K_2 are taken to be 3MPa assuming that the lot considered as the project is fifth lot and above. Among the two criteria's set, criterion 1 which is applicable for small lots is used for this analysis for each lot is three samples is considered. The standard deviation decided on the research perspective that the closeness among result of three samples from one another. To use table that is taken from table ACI standard of concrete quality control for standard deviation. General construction is taken and the Excellency or poorness will be decided based on the test result for 7th, 14th, 28th and 45th days. The results collected from the two consultants depicted as follow:

$m_{3\geq f_{ck}} + k_1$……4.5a

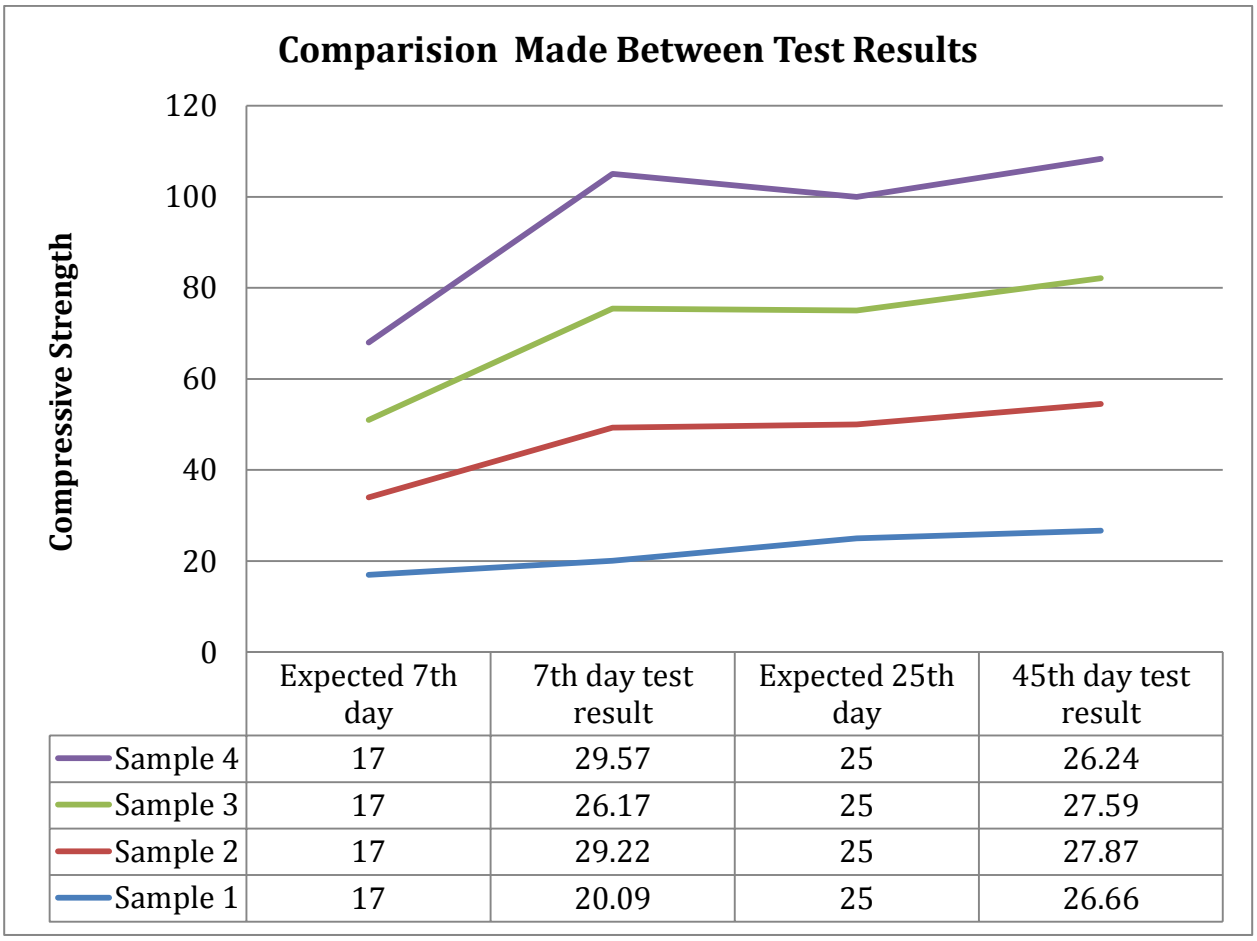
$x_{1\geq f_{ck}} - k_2$……4.5b

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Compressive strength (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	3rd Floor Slab	7	23.72	*26.65*	25	3	3	23.72	28	22	Not Complied	Complied	Not Complied
2			29.05										
3			27.19										

26.65≥25+3=28….. Not Complied
23.72≥25-3=22…….. Complied } Not Complied

In order for these compliance criteria to happen the two simultaneous equations has to be satisfied. The other attachments are attached at the appendix.From the above table it is clearly shown that there is both compliance of test result this is due to especially 7th day result is almost 28th rather the non-compliance of test result is exaggerated as compare to 28th and 45th day. But

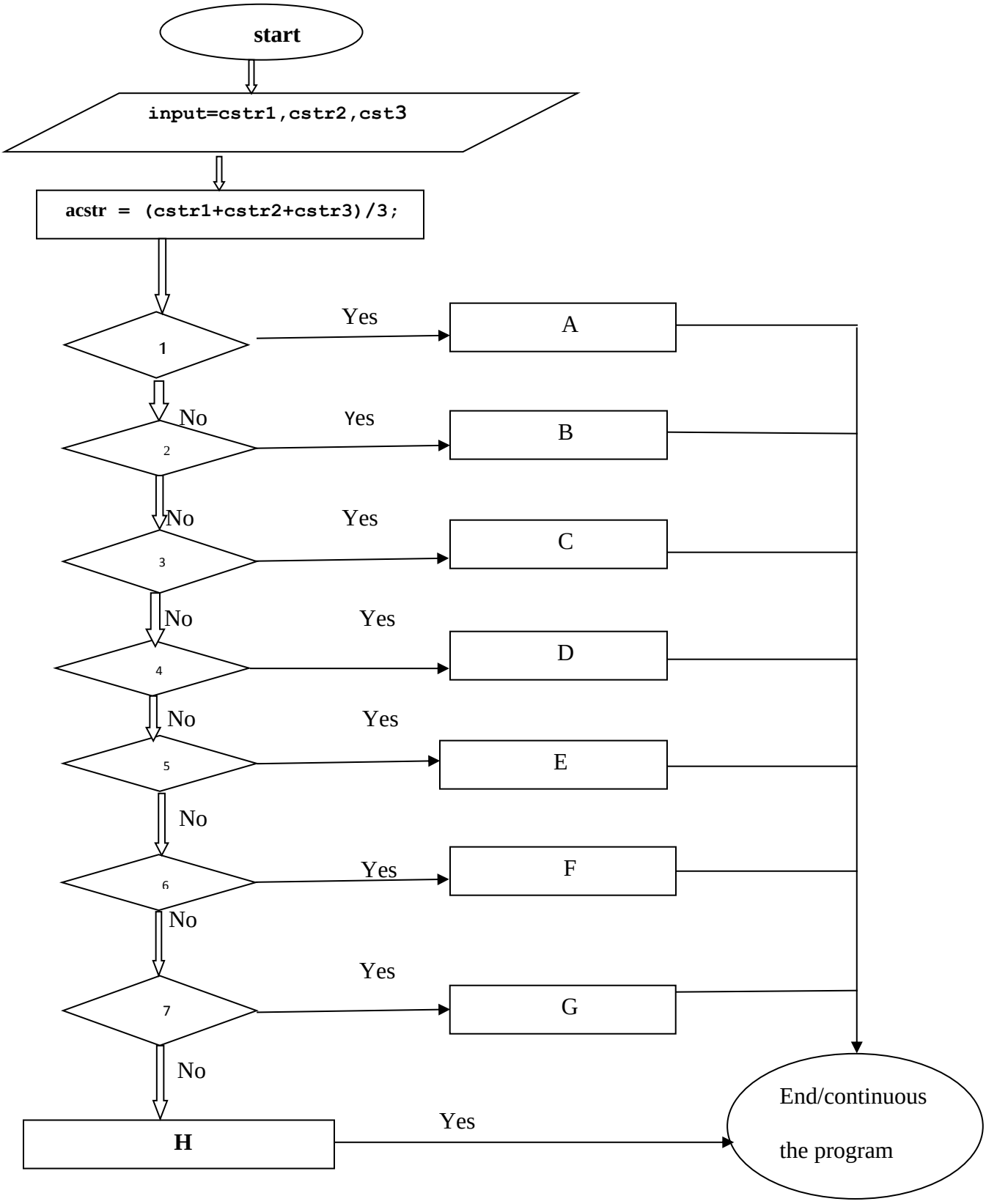
the result still had problem because if comparisons were made between 7th and 45th day the second one slightly greater result as compare to the first one.



	Expected 7th day	7th day test result	Expected 25th day	45th day test result
Sample 4	17	29.57	25	26.24
Sample 3	17	26.17	25	27.59
Sample 2	17	29.22	25	27.87
Sample 1	17	20.09	25	26.66

Fig 4.6. Sample Taken from Active Site

For further investigation engineering software called Math Lab in which it was used for decision making purpose. From the above table it is clearly shown that there were result consists of compliance and non-compliance. But both results were depending on the test results collected from two consulting. Therefore, further software is needed to get the most reliable result and used for future purpose.

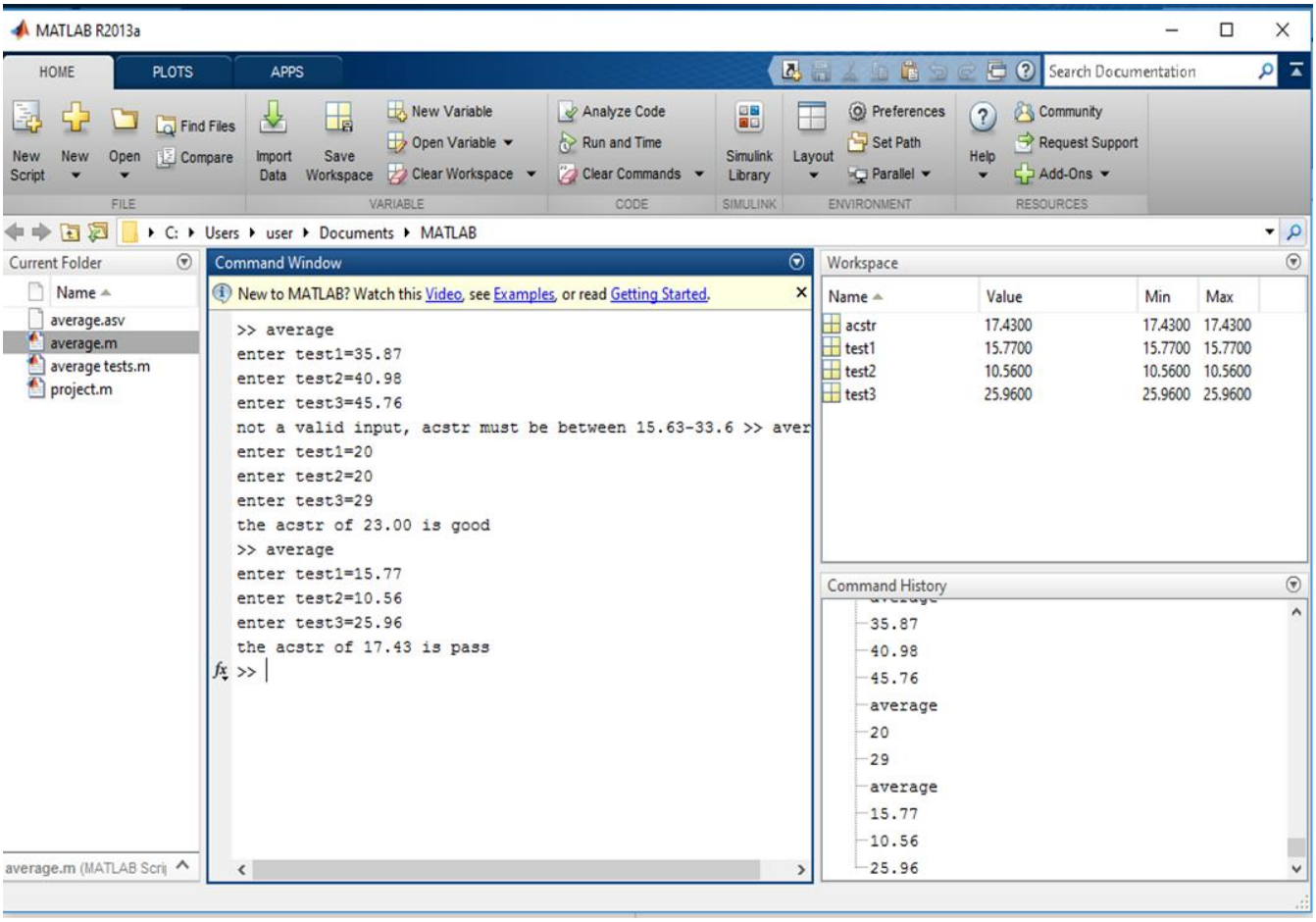

start
input=cstr1,cstr2,cst3
acstr = (cstr1+cstr2+cstr3)/3;
1
Yes
A
No
2
Yes
B
No
3
Yes
C
No
4
Yes
D
No
5
Yes
E
No
6
Yes
F
No
7
Yes
G
No
H
Yes
End/continuous
the program

```
%%User inputs avalue of the cstr
cstr1 = input('enter in a cstr1,');
cstr2 = input('enter in a cstr2:');
cstr3 = input('enter in a cstr3:');
acstr = (cstr1+cstr2+cstr3)/3;
%%Is the acstr 33.6 or less(if it is then print in valid input)
if acstr <=33.6 && acstr >=15.63

    if acstr>=30.6
      %%excellent=30.6+
      fprintf( 'the acstr of %.2f is excellent \n',acstr);
    elseif acstr>=28.87
       %%fail=28.87+(but lessthan30.6)
       fprintf( 'the acstr of %.2f is fail \n',acstr);
    elseif acstr>=25.86
       %%very good=25.86+(but lessthan28.87)
       fprintf( 'the acstr of %.2f is very good \n',acstr);
    elseif acstr>=24.21
       %%fail=24.21+(but lessthan25.86)
       fprintf( 'the acstr of %.2f is fail \n',acstr);
    elseif acstr>=21.2
       %%good=21.2+(but lessthan24.21)
       fprintf( 'the acstr of %.2f is good \n',acstr);
    elseif acstr>=18.64
       %%fail=18.64+(but lessthan21.2)
       fprintf( 'the acstr of %.2f is fail \n',acstr);
    elseif acstr>=15.63
       %%pass=15.63+(but lessthan18.64)
       fprintf( 'the acstr of %.2f is pass \n',acstr);
    else
       %%fail is less than 15.63
       fprintf( 'the acstr of %.2f is fail\n',acstr);
    end

else
     %%the input was invalid
     fprintf( 'not a valid input, acstr must be between 15.63-33.6 ');
end
```

flow chart Key

1. acstr>=30.6
2. elseif acstr>=28.87
3. elseif acstr>=25.86
4. elseif acstr>=24.21
5. elseif acstr>=21.2
6. elseif acstr>=18.64
7. elseif acstr>=15.63

A. excellent
B. fail
C. very good
D. fail
E. good
F. fail
G. pass
H. fail



CHAPTER SIX

KEY FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter presents the major summary of research findings, conclusion and recommendation of the study. The conclusions of this study are based on the summary of research findings and the recommendation part is presented based on the conclusions.

5.1 Summary of Major Findings

Quality in the construction environment is complex as the industry is dynamic in nature. There are many factors which may influence the quality of a product. Quality of a product in construction can be defined when a unit or element is fit for its intended purpose, meets the requirements of the design specification, and aesthetics. Thus, it needs to be user friendly, durable, safe, free from defects and free from significant variations.

Thus in this research paper, explanatory and descriptive survey analysis were performed on concrete quality control in Addis Ababa Housing Construction Project (AAHCPO) the case of Akaki Kality Branch project office at Koye fech construction site. This research used both quantitative and qualitative research approaches and targeted 90 respondents of contractor's, consultant's and client's staff. However out of the total distributed questionnaires, 83 questionnaires were properly filled and returned and analyzed using quantitative analysis. This indicated 92.2% response rate.

According to the analysis and discussions carried out in chapter four the researcher summarized the following major key research findings:

The questionnaire consists two parts, the first part comprise the demographic or the general information of the respondents, part two comprise seven category questionnaires related to quality control procedures and cause to produce low quality concrete material in AAHCPO the case of Akaki Kality construction branch project. Based on this study used descriptive statistics like frequency, percentage, mean and standard deviation to calculate the respondents opinion related to the questioners using statistical package for social science (SPSS) software version 22.

The demographic or the general part of the questionnaires was calculated and analyzed using frequency and percentage. Part two of the questionnaires were calculated using mean and standard deviation to know respondents level of agreement toward each items. Part two comprises seven categories and a total of 33 items. According to these the following key findings identified and they may be the major problems causing poor quality concrete production.

The quality of sand that is provided by contractor not free from organic impurities and it contains high silt content, the cement bag is not properly placed on timber platform to protect moisture and they are not using the cement according to the firs comes first will be used, the aggregates are not stored properly in self-draining form/like in hogging form, the grading size of coarse aggregate to some extent do not fulfills the required specification, there is no a mechanism to check the required workability such as using slump/cone test, there is no a mechanism of proportion of water cement ratio for production of concrete, the project does not keeps the appropriate curing time tor caste concrete, the contractors are not use water spraying or covering sheets during curing period of casted concrete, the minimum casting days are not kept for curing casted concrete, no hammer test was done if the 7th or 28th day of the sample test fails, the consultants do not have sufficient work experience and knowledge related to quality control, contractors have not got appropriate awareness and training related quality concrete production process and similarly MSEs have not sufficient quality concrete production experience and knowledge.

5.2 Conclusion

Based on the research finding related to concrete quality control and practices a study conducted at Koye Fech construction site concluded as follows:

The quality of sand that is provided by contractors contains organic substance, contractors are unable to place cements in proper way like on flat timber plat form and on the client side the aggregates are not placed in a drained or hogging form to avoid absorption of moisture. The presence of these factors leads poor concrete production on the site. The water that they used was clean but the water container was not properly kept clean and in the long time it develops organic substance and this cause’s poor quality production.

There is no a mechanism such as slump or cone test to check the required workability and proportion of water cement ratio for production of concrete. Due to this the project is also unable to check proportion of water cement ratio for production of concrete. Absence of such checking mechanism on construction site had not able to detect weather the concrete fulfill the required strength or not and will lead to poor concrete production. Moreover, the mixing time has also effect on concrete strength and quality.

On the construction site to transport the mixed concrete they use wheel barrow, barrela and winch. Improper use of such transportation has also effect on concrete production. Usually for vertical transportation they use winch and on floor they use *barella*. Moreover, on construction site they use vibrators to compact the concrete but they apply over or under pressure on the concrete. This led the concrete to lose the required strength and quality.

Related to concrete curing time, the project does not keeps the curing time, the project does not use water spraying or covering sheets the concrete during curing periods and also the project does not keeps the minimum seven days for casted concrete. These lead to poor concrete production on the site and the concrete lose the strength and quality. These results also associated with inefficient knowledge and low work experience of workmanship related to concrete quality control on production site. Therefore, the above all results are the implication of poor quality control because one of quality checking mechanism is compressive test result this implies that the overall quality of the ingredients would affect the output result. According to Ethiopia code of standard the compliance criteria shows that most of the test results were not fulfil the compliance criteria.

5.3 Recommendations

- Concrete construction materials such as aggregates, cements and waters should be passed through necessary tests; all specified tests have to be done in accordance with standard procedures before use and handled (stocked) properly in the site to prevent from any harm full effects, in addition to this aggregate source have to be identified and studied on its mineralogical contents and cement producing factories should specify the date of production of cement so that concrete producers know whether the cement is aged or not easily. Consultants on the site must pay attention for construction of water tankers by providing the fence and cover in order to ensure safety for human and protect from dust and other foreign matter which affect quality of concrete.
- Production process must be carried out under careful controlling, starting from batching to curing. For instance concrete production should be produced by proportioning of ingredients based on their property and by providing appropriate mixing time and slump, but failing slumps shouldn't be corrected by adding or reducing amount of water and then compaction should be done on appropriate time, spacing and depth. Finally curing time must depend on the type of cement used whether (whether it is PPC or OPC) and must be cured sufficiently by considering necessary prevention mechanism from evaporation of water from the surface.
- Regular checking the quality of sand that by using jar test and before the sand dumped on the site, also the cost of sand that is free form organic substance has to be rejected from the site as soon as the problem examined and if all stake holders were well trained that the impact all the ingredient quality in selecting, handling, mixing, transporting, placing, compacting, curing and testing.
- The handling of aggregates both coarse and fine aggregate should be better to be stored in the form of in self-draining form in order to drain the moisture that is was store by different means such as by rain water and avoiding pores substance in coarse aggregate would maintained water cement ratio.
- Regularly follow the grading size of coarse aggregate to fulfills the required specification

- Applying a mechanism to check the required workability by using slump/cone test has been crucial in order to maintain consistency and strength and quality level could be clearly visible.
- Should create a controlling to mechanism to check proportion of water cement ratio for production of concrete.
- Keep the appropriate curing time to enhance the quality of concrete and done hammer test if it fails the first test result.
- There must be well-experienced professionals both on the contractor and the consulting staff to improve quality. In addition to this, consultants must have enough man power for controlling purpose as observation some consultants assign one site inspector for one production area, and one site is observed which is visited once a week by supervisors in the case of precast beam production.

Suggestion for future work

1. The purpose of avoiding use of light weight sand(pumice) in production of concrete in cost efficient housing
2. Driving mechanism in order to check the quality of concrete making materials
3. How to increase in number of well-experienced professionals both on the contractor and the consulting in condominium houses

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APPENDIX

PART A

Addis Ababa Science and Technology University

Questionnaires for Stakeholders/ contractors, consultants and client/

Dear Sir/madam

Thank you for taking your precious time to respond for this questionnaire. The questionnaires are a research instrument for fulfillment of my MSc thesis. My research topic title is "Investigation on quality control for concrete materials in Addis Ababa Housing Construction Project (AAHCPO): A case of Akaki Kality Housing Branch Office Project."

The questionnaires listed below are attempted to respond the quality control for concrete materials in (AAHCPO). Hence, your responses are highly valuable to finalize my thesis.

Therefore, the information that you provide will be used purely for academic purposes and will be kept strictly confidential. You do not need to write your name or personal related issues. Finally, I would like to thank you very much for your cooperation and sparing your valuable time for my request. Please tick one box below to show how much you agree or disagree with the given questions.

With regards,

Mekdese Tesema

Part One: General Information of the respondents

1.1 You are currently working as employee of

A Contractor B) Consultant C) Client

1.2 What is the highest level of education you have completed?

A) TVET Certificate B) College Diploma

C) University Degree D) MSC/MA

1.3 How long have you been working in construction project?

A, less than 1 year B, 1 -5 years

C, 5- 10 years D) More than 10 years

1.4 Your current job position in your organization

A) Resident engineer B) Site engineer

C) Project manager D) MSEs Staff

1.5 Did you have taken concrete quality control procedure training in your organization?

A) Yes B to some extent C) Not at all

Part Two: The following questionnaires are related to quality control for concrete material in AAHCPO. From your experience, please express your opinion on the importance or give rank on the following determinant factors as major causes of poor quality of concrete material in the AAHCPO at Koye Feche construction site. (Please tick (✓) the appropriate column according to their degree of rank. Rank of your response: 1= Strongly Disagree (SD), 2= Disagree (D), 3= Uncertain (N), 4 = Agree (A) and 5= Strongly Agree (SA).

Items	SD (1)	D (2)	N (3)	A (4)	SA (5)
Material Handling					
For Cement, (Coarse, Fine) aggregate and Water					
1. There is a mechanism that is used to control the quality of ingredients for concrete production?					
2. There is field test for sand and it is clean i.e. free from organic impurities, low silt content.					
3. The contractors use First in first out (FIFO) principle?					
4. The quality of coarse aggregate fulfills the required specification such as hardness, free from materials that likely to be decomposes and shows change in volume when exposed to weather; there is problem of flakiness and elongation index?					
5.The aggregate are stored properly in self-draining form/like in hogging form / 					
6. The grading size of coarse aggregate fulfills the specification?					
7. The type of water that is used for mixing concrete is potable/drinkable					

8. The quality of pasca that is used for storage of water questionable					
9. Different mechanism will be used if the container is contaminated					
10. Applying cement on to water container that is contaminated will give the required solution? is					
11. Rain water will be used for concrete production in the cases of have no water on site					
Items	**SD (1)**	**D (2)**	**N (3)**	**A (4)**	**SA (5)**
Material Mixing					
1. There is mechanism to check the required workability by using slump/cone test					
2. In the production of concrete proportioning of water cement ratio is done					
3. The box size of aggregates that is used for production of C-25 concrete is 40*50*18					
4. Most of the contractors, they have no their own use mixer for concrete production					
The procedures that commonly used for mixing concrete in bathing plant is **water → coarse agg+sand agg → cement → coarse agg+sand agg → water**					
5. The bulking of sand will affect the proportion of concrete					
Material Transport					
1. Do you use wheel barrow for transporting concrete					
Material Placing					
1. Over vibration has an effect on segregation					
2. The height of placing concrete on to form has an effect					
3.The time of curing for casted concrete has an effective					
4. Water spraying or covering sheets for period of curing for casted concrete is used					
5. Concrete cube test taken for given of executed work is at the end of casting					
6. Rebar with dia #16 is used for compaction purpose therefore its length has compacting effect in preparing concrete cube sample with size of 15*15*15cm					

Interview Questionnaire for Client

Thank you for your cooperation and sparing your valuable time for this interview. The interview questions are a research instrument for the fulfillment of MSC program and study. Your responses will be completely anonymous and confidential and will not be identified by individual.

Question:

1. What are the general procedures used to produce concrete making materials at construction site? Regarding handling materials, concrete production process, placement, testing, curing and workmanship?

_____

_____

_____

2. Do the MSEs are well experienced in concrete materials handling, production, transporting, placing, casting, testing and curing?

_____

_____

_____

3. How does precast beam produced and supplied by MSEs are controlled and monitored on the project site?

_____

_____

_____

4. What parameters and test you check and conduct on concrete materials? Please specify if any
    a. Tests conducted on cement such as finesse, age, First in First Out and Last in First Out.

    _____

    _____

    b. Tests conducted on coarse aggregates (soundness, flakiness, elongated, free from porous, free from inorganic materials and gradation? How often do you take sample for test?

_____

_____

_____

c. Tests conducted on fine aggregates/sand (silt content & visual inspection). How often you the consultant take sample? Do the contractors have any reliable suppliers?

_____

_____

_____

d. Tests conducted on water if any. Is the water potable (drinkable) or you are using other sources for concrete production? Please specify if any,

_____

e. Is the water container clean and free from impurities?

_____

f. Do the contractors use rain water in the case of have no water?

5. What are the basic problems faced to produce the quality of concrete materials related to contractors, consultants and MSEs?

_____

_____

6. Do you think sufficient and qualified personnel available on the site related to quality concrete material production and control?

_____

7. What preventive and control methods you advice in order to enhance the current concrete production practices on those public projects?

_____

_____

Interview Questionnaire for Contractors

Thank you for your cooperation and sparing your valuable time for this interview. The interview questions are a research instrument for the fulfillment of MSC program and study. Your responses will be completely anonymous and confidential and will not be identified by individual.

Question:

8. What are the procedures used to produce concrete making materials at construction site? Regarding handling materials, concrete production process, placement, testing, curing and workmanship?

_____
_____
_____
_____

9. What are the commonly used procedures that you follow in order to produce good quality concrete on the koye fetch project site.

_____
_____
_____
_

10. Do you have a guideline to produce concrete quality control on site?
    a. If so do you strictly follow the guideline?
    b. If not reason out?
    c. How do you compare your guideline with other national quality control guideline?

_____
_____
_____

11. What parameters and test you check and conduct on concrete materials? Please specify if any

a. Tests conducted on cement such as finesse, age, First in First Out and Last in First Out.

_____

b. Tests conducted on coarse aggregates (soundness, flakiness, elongated, free from porous? How often you take sample for test?

_____

c. Tests conducted on fine aggregates/sand (silt content & visual inspection). How often you take sample? Do you have any reliable suppliers?

_____

d. Tests conducted on water if any. Is the water potable (drinkable) or you are using other sources for concrete production? Please specify if any,

_____

e. Is the water container clean and free from impurities?

_____

12. What precaution and corrective measures you take in concrete transporting and placing? Horizontally and vertically in related to segregation, slump loss, loss of ingredients and formation of cold joints

_____

_____

_____

13. Do you think sufficient and qualified personnel available on the site related to quality concrete material production and control?

_____

_____

_____

14. What preventive and control methods you advice in order to enhance the current concrete production practices on those public projects?

_____

_____

_____

PART B

Table 4.15. 7th Compressive Strength test results and analysis, according to EBCS-2 1995

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	7	25.93	*26.17*	25	3	3	25.53	28	22	Not Complied	Complied	Not Complied
2			25.53										
3			27.06										
1	Footing Pad	7	29.08	*29.22*	25	3	3	28.57	28	22	Complied	Complied	Complied
2			28.57										
3			30										
1	Footing Pad	7	29.2	*29.57*	25	3	3	27.63	28	22	Complied	Complied	Complied
2			31.87										
3			27.63										
1	Footing Pad	7	21.34	*20.09*	25	3	3	19	28	22	Not Complied	Not Complied	Not Complied
2			19.93										
3			19										
1	Footing Pad	7	23.18	*21.72*	25	3	3	19.9	28	22	Not Complied	Not Complied	Not Complied
2			22.09										
3			19.9										
1	Footing Pad	7	23.18	*21.72*	25	3	3	19.9	28	22	Not Complied	Not Complied	Not Complied
2			22.09										
3			19.9										
1	Footing Pad	7	8.72	*13.16*	25	3	3	8.72	28	22	Not Complied	Not Complied	Not Complied
2			15.01										
3			15.76										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	7	21.85	*27.25*	25	3	3	17.87	28	22	Not Complied	Not Complied	Not Complied
2			42.04										
3			17.87										
1	Footing Pad	7	12.6	*21.59*	25	3	3	12.6	28	22	Not Complied	Not Complied	Not Complied
2			15.57										
3			36.59										
1	Footing Pad	7	26.6	*29.93*	25	3	3	26.6	28	22	Complied	Complied	Complied
2			32.7										
3			30.5										
1	Footing Pad	7	27	*28.00*	25	3	3	25.8	28	22	Complied	Complied	Complied
2			31.2										
3			25.8										
1	Footing Pad	7	41.7	*40.93*	25	3	3	39	28	22	Complied	Complied	Complied
2			39										
3			42.1										
1	Footing Pad	7	25.5	*27.17*	25	3	3	25.5	28	22	Not Complied	Complied	Not Complied
2			28.2										
3			27.8										
1	Footing Pad	7	20.45	*20.27*	25	3	3	20.04	28	22	Not Complied	Not Complied	Not Complied
2			20.31										
3			20.04										
1	Footing Pad	7	20.45	*20.27*	25	3	3	20.04	28	22	Not Complied	Not Complied	Not Complied
2			20.31										
3			20.04										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	f_{ck}+k_1=A	f_{ck}-k_2=B	m_3 >=f_{ck}+k_1	x_1 >=f_{ck} -k_2	Decision According to EBCS-2: 1995
1	Footing Pad	7	19.78	*18.72*	25	3	3	17.9	28	22	Not Complied	Not Complied	Not Complied
2			18.48										
3			17.9										
1	Footing Pad	7	22.44	*22.70*	25	3	3	22.44	28	22	Not Complied	Complied	Not Complied
2			22.47										
3			23.2										
1	Footing Pad	7	27.8	*25.21*	25	3	3	23.04	28	22	Not Complied	Complied	Not Complied
2			23.04										
3			24.8										
1	Footing Pad	7	24.84	*25.50*	25	3	3	24.35	28	22	Not Complied	Complied	Not Complied
2			27.32										
3			24.35										
1	Footing Pad	7	24.84	*25.50*	25	3	3	24.35	28	22	Not Complied	Complied	Not Complied
2			27.32										
3			24.35										
1	Footing Pad	7	32.46	*33.41*	25	3	3	32.46	28	22	Complied	Complied	Complied
2			34.76										
3			33										
1	Footing Pad	7	16.67	*19.26*	25	3	3	16.67	28	22	Not Complied	Not Complied	Not Complied
2			19.47										
3			21.64										
1	Footing Pad	7	31.37	*29.86*	25	3	3	27.32	28	22	Complied	Complied	Complied
2			30.88										
3			27.32										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	7	27.87	*27.75*	25	3	3	26.95	28	22	Not Complied	Complied	Not Complied
2			26.95										
3			28.42										
1	Footing Pad	7	23.15	*23.11*	25	3	3	22.35	28	22	Not Complied	Complied	Not Complied
2			23.84										
3			22.35										
1	Footing Pad	7	23.96	*25.26*	25	3	3	21.81	28	22	Not Complied	Not Complied	Not Complied
2			21.81										
3			30.02										
1	Footing Pad	7	20.63	*17.77*	25	3	3	15.13	28	22	Not Complied	Not Complied	Not Complied
2			17.56										
3			15.13										
1	Footing Pad	7	24.23	*25.24*	25	3	3	24.23	28	22	Not Complied	Complied	Not Complied
2			26.45										
3			25.05										
1	Footing Pad	7	22.31	*22.92*	25	3	3	22.31	28	22	Not Complied	Complied	Not Complied
2			23.64										
3			22.82										
1	Footing Pad	7	27.32	*27.92*	25	3	3	26.42	28	22	Not Complied	Complied	Not Complied
2			26.42										
3			30.03										
1	Footing Pad	7	25.97	*25.70*	25	3	3	24.18	28	22	Not Complied	Complied	Not Complied
2			24.18										
3			26.94										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	7	25.6	*27.20*	25	3	3	25.6	28	22	Not Complied	Complied	Not Complied
2			28.6										
3			27.4										
1	Footing Pad	7	25.4	*28.17*	25	3	3	25.4	28	22	Complied	Complied	Complied
2			31.4										
3			27.7										
1	Footing Pad	7	28.8	*27.27*	25	3	3	25.6	28	22	Not Complied	Complied	Not Complied
2			25.6										
3			27.4										
1	Footing Pad	7	27.6	*30.10*	25	3	3	27.6	28	22	Complied	Complied	Complied
2			31.7										
3			31										
1	Footing Pad	7	19.644	*21.69*	25	3	3	17.38	28	22	Not Complied	Not Complied	Not Complied
2			17.378										
3			28.053										
1	Footing Pad	7	21.35	*21.47*	25	3	3	21.12	28	22	Not Complied	Not Complied	Not Complied
2			21.95										
3			21.12										
1	Footing Pad	7	21.35	*21.47*	25	3	3	21.12	28	22	Not Complied	Not Complied	Not Complied
2			21.95										
3			21.12										
1	Footing Pad	7	25.43	*24.02*	25	3	3	22.07	28	22	Not Complied	Complied	Not Complied
2			22.07										
3			24.55										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Ground Elev'n Clo.	7	18.69	*21.24*	25	3	3	18.69	28	22	Not Complied	Not Complied	Not Complied
2			21.84										
3			23.18										
1	Ground Elev'n Clo.	7	22.47	*21.00*	25	3	3	19.04	28	22	Not Complied	Not Complied	Not Complied
2			21.49										
3			19.04										
1	Ground Elev'n Clo.	7	24.01	*22.71*	25	3	3	20.63	28	22	Not Complied	Not Complied	Not Complied
2			20.63										
3			23.49										
1	Ground Elev'n Clo.	7	23.2	*22.21*	25	3	3	20.7	28	22	Not Complied	Not Complied	Not Complied
2			22.74										
3			20.7										
1	Ground Elev'n Clo.	7	22.48	*21.59*	25	3	3	20.47	28	22	Not Complied	Not Complied	Not Complied
2			21.81										
3			20.47										
1	Ground Elev'n Clo.	7	28.5	*28.71*	25	3	3	27.3	28	22	Not Complied	Complied	Not Complied
2			30.33										
3			27.3										
1	Ground Elev'n Clo.	7	28.93	*27.42*	25	3	3	25.48	28	22	Not Complied	Complied	Not Complied
2			25.48										
3			27.86										
1	Ground Elev'n Clo.	7	25.55	*24.62*	25	3	3	22.55	28	22	Not Complied	Complied	Not Complied
2			25.76										
3			22.55										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	f_{ck}+k_1=A	f_{ck}-k_2=B	m_3 >=f_{ck}+k_1	x_1 >=f_{ck} -k_2	Decision According to EBCS-2: 1995
1	Ground Elev'n Clo.	7	21.4	*20.26*	25	3	3	18.92	28	22	Not Complied	Not Complied	Not Complied
2			20.47										
3			18.92										
1	Ground Elev'n Clo.	7	23.75	*23.53*	25	3	3	22.67	28	22	Not Complied	Complied	Not Complied
2			22.67										
3			24.18										
1	Ground Elev'n Clo.	7	15.39	*16.13*	25	3	3	15.39	28	22	Not Complied	Not Complied	Not Complied
2			16.35										
3			16.65										
1	Ground Elev'n Clo.	7	24.91	*24.93*	25	3	3	24.61	28	22	Not Complied	Complied	Not Complied
2			24.61										
3			25.28										
1	Ground Elev'n Clo.	7	22.37	*22.75*	25	3	3	21.85	28	22	Not Complied	Not Complied	Not Complied
2			24.02										
3			21.85										
1	Ground Elev'n Clo.	7	21.69	*21.90*	25	3	3	21.69	28	22	Not Complied	Not Complied	Not Complied
2			22.13										
3			21.87										
1	Ground Elev'n Clo.	7	21.69	*21.90*	25	3	3	21.69	28	22	Not Complied	Not Complied	Not Complied
2			22.13										
3			21.87										
1	Ground Elev'n Clo.	7	23.71	*22.17*	25	3	3	21.27	28	22	Not Complied	Not Complied	Not Complied
2			21.54										
3			21.27										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	1st Floor Slab	7	19.12	*20.34*	25	3	3	19.12	28	22	Not Complied	Not Complied	Not Complied
2			19.64										
3			22.26										
1	1st Floor Slab	7	23.71	*22.17*	25	3	3	21.27	28	22	Not Complied	Not Complied	Not Complied
2			21.54										
3			21.27										
1	1st Floor Slab Floor	7	19.86	*21.40*	25	3	3	19.86	28	22	Not Complied	Not Complied	Not Complied
2			22.68										
3			21.67										
1	1st Floor Slab	7	21.7	*22.54*	25	3	3	21.7	28	22	Not Complied	Not Complied	Not Complied
2			23.21										
3			22.71										
1	1st Floor Slab	7	21.97	*22.51*	25	3	3	21.97	28	22	Not Complied	Not Complied	Not Complied
2			23.14										
3			22.43										
1	1st Floor Slab	7	28.98	*30.19*	25	3	3	28.98	28	22	Complied	Complied	Complied
2			31.19										
3			30.4										
1	1st Floor Slab	7	21.98	*21.61*	25	3	3	21.12	28	22	Not Complied	Not Complied	Not Complied
2			21.12										
3			21.72										
1	1st Floor Slab	7	21.41	*19.68*	25	3	3	18.54	28	22	Not Complied	Not Complied	Not Complied
2			19.09										
3			18.54										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	1st Floor Slab	7	18.95	*19.19*	25	3	3	18.77	28	22	Not Complied	Not Complied	Not Complied
2			19.86										
3			18.77										
1	1st Floor Slab	7	18.25	*20.02*	25	3	3	18.25	28	22	Not Complied	Not Complied	Not Complied
2			19.9										
3			21.9										
1	1st Floor Slab	7	22.13	*20.94*	25	3	3	20.09	28	22	Not Complied	Not Complied	Not Complied
2			20.09										
3			20.6										
1	1st Floor Slab	7	19.65	*19.97*	25	3	3	18.72	28	22	Not Complied	Not Complied	Not Complied
2			18.72										
3			21.54										
1	1st Floor Slab	7	24.19	*22.21*	25	3	3	19.87	28	22	Not Complied	Not Complied	Not Complied
2			22.58										
3			19.87										
1	1st Floor Slab	7	17.91	*18.89*	25	3	3	17.91	28	22	Not Complied	Not Complied	Not Complied
2			19.1										
3			19.67										
1	1st Floor Slab	7	18.607	*17.99*	25	3	3	16.47	28	22	Not Complied	Not Complied	Not Complied
2			18.906										
3			16.468										
1	1st Floor Slab	7	22.45	*21.30*	25	3	3	18.36	28	22	Not Complied	Not Complied	Not Complied
2			18.36										
3			23.1										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	2nd Floor Slab	7	20.68	*21.86*	25	3	3	20.68	28	22	Not Complied	Not Complied	Not Complied
2			22.76										
3			22.13										
1	2nd Floor Slab	7	22.14	*22.00*	25	3	3	21.83	28	22	Not Complied	Not Complied	Not Complied
2			22.03										
3			21.83										
1	2nd Floor Slab	7	21.35	*21.26*	25	3	3	19.63	28	22	Not Complied	Not Complied	Not Complied
2			22.79										
3			19.63										
1	2nd Floor Slab	7	21.51	*20.21*	25	3	3	18.78	28	22	Not Complied	Not Complied	Not Complied
2			20.35										
3			18.78										
1	2nd Floor Slab	7	21.47	*22.10*	25	3	3	21.47	28	22	Not Complied	Not Complied	Not Complied
2			22.74										
3			22.1										
1	2nd Floor Slab	7	18.57	*19.70*	25	3	3	18.28	28	22	Not Complied	Not Complied	Not Complied
2			22.25										
3			18.28										
1	2nd Floor Slab	7	20.54	*20.87*	25	3	3	18.95	28	22	Not Complied	Not Complied	Not Complied
2			23.13										
3			18.95										
1	2nd Floor Slab	7	21.53	*22.77*	25	3	3	21.53	28	22	Not Complied	Not Complied	Not Complied
2			22.9										
3			23.88										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	2nd Floor Slab	7	21.54	*21.26*	25	3	3	19.55	28	22	Not Complied	Not Complied	Not Complied
2			22.68										
3			19.55										
1	2nd Floor Slab	7	27.29	*25.85*	25	3	3	23.2	28	22	Not Complied	Complied	Not Complied
2			23.2										
3			27.06										
1	2nd Floor Slab	7	20.67	*23.58*	25	3	3	20.67	28	22	Not Complied	Not Complied	Not Complied
2			25.9										
3			24.17										
1	2nd Floor Slab	7	25.43	*26.24*	25	3	3	25.43	28	22	Not Complied	Complied	Not Complied
2			27.23										
3			26.07										
1	2nd Floor Slab	7	27.72	*26.85*	25	3	3	26.06	28	22	Not Complied	Complied	Not Complied
2			26.78										
3			26.06										
1	2nd Floor Slab	7	20.66	*21.68*	25	3	3	20.66	28	22	Not Complied	Not Complied	Not Complied
2			22.69										
3			21.7										
1	2nd Floor Slab	7	18.78	*21.42*	25	3	3	18.78	28	22	Not Complied	Not Complied	Not Complied
2			23.57										
3			21.9										
1	2nd Floor Slab	7	23.05	*22.79*	25	3	3	21.33	28	22	Not Complied	Not Complied	Not Complied
2			21.33										
3			24										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	3rd Floor Slab	7	23.72	*26.65*	25	3	3	23.72	28	22	Not Complied	Complied	Not Complied
2			29.05										
3			27.19										
1	3rd Floor Slab	7	43.54	*40.38*	25	3	3	37.54	28	22	Complied	Complied	Complied
2			40.07										
3			37.54										
1	3rd Floor Slab	7	18.72	*18.39*	25	3	3	18.13	28	22	Not Complied	Not Complied	Not Complied
2			18.32										
3			18.13										
1	3rd Floor Slab	7	27.61	*27.67*	25	3	3	27.06	28	22	Not Complied	Complied	Not Complied
2			27.06										
3			28.33										
1	3rd Floor Slab	7	23.7	*25.70*	25	3	3	23.7	28	22	Not Complied	Complied	Not Complied
2			27.25										
3			26.15										
1	3rd Floor Slab	7	21.53	*20.93*	25	3	3	18.45	28	22	Not Complied	Not Complied	Not Complied
2			18.45										
3			22.8										
1	3rd Floor Slab	7	25.94	*26.27*	25	3	3	25.94	28	22	Not Complied	Complied	Not Complied
2			26.66										
3			26.22										
1	3rd Floor Slab	7	19.28	*20.70*	25	3	3	19.28	28	22	Not Complied	Not Complied	Not Complied
2			22.1										
3			20.73										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	3rd Floor Slab	7	25.65	*22.71*	25	3	3	19.62	28	22	Not Complied	Not Complied	Not Complied
2			19.62										
3			22.86										
1	3rd Floor Slab	7	21.67	*21.07*	25	3	3	18.76	28	22	Not Complied	Not Complied	Not Complied
2			22.79										
3			18.76										
1	3rd Floor Slab	7	29.78	*26.98*	25	3	3	23.89	28	22	Not Complied	Complied	Not Complied
2			23.89										
3			27.28										
1	3rd Floor Slab	7	16.56	*17.81*	25	3	3	16.56	28	22	Not Complied	Not Complied	Not Complied
2			17.21										
3			19.67										
1	3rd Floor Slab	7	22.45	*22.61*	25	3	3	21.7	28	22	Not Complied	Not Complied	Not Complied
2			23.67										
3			21.7										
1	3rd Floor Slab	7	16.78	*17.34*	25	3	3	16.78	28	22	Not Complied	Not Complied	Not Complied
2			18.1										
3			17.13										
1	3rd Floor Slab	7	20.93	*23.01*	25	3	3	20.93	28	22	Not Complied	Not Complied	Not Complied
2			25.71										
3			22.38										
1	3rd Floor Slab	7	21.54	*21.06*	25	3	3	18.95	28	22	Not Complied	Not Complied	Not Complied
2			22.7										
3			18.95										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	4th Floor Slab	7	30.27	*26.33*	25	3	3	23.9	28	22	Not Complied	Complied	Not Complied
2			24.81										
3			23.9										
1	4th Floor Slab	7	27.33	*27.30*	25	3	3	26.15	28	22	Not Complied	Complied	Not Complied
2			28.42										
3			26.15										
1	4th Floor Slab	7	27.87	*27.50*	25	3	3	27.21	28	22	Not Complied	Complied	Not Complied
2			27.21										
3			27.42										
1	4th Floor Slab	7	18.26	*18.67*	25	3	3	18.23	28	22	Not Complied	Not Complied	Not Complied
2			19.52										
3			18.23										
1	Footing Pad	7	20.31	*21.27*	25	3	3	20.31	28	22	Not Complied	Not Complied	Not Complied
2			22.48										
3			21.02										
1	4th Floor Slab	7	20.01	*19.13*	25	3	3	18.28	28	22	Not Complied	Not Complied	Not Complied
2			19.1										
3			18.28										
1	4th Floor Slab	7	21.62	*21.00*	25	3	3	18.98	28	22	Not Complied	Not Complied	Not Complied
2			18.98										
3			22.39										
1	4th Floor Slab	7	28.16	*27.70*	25	3	3	21.71	28	22	Not Complied	Not Complied	Not Complied
2			21.71										
3			33.23										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	4th Floor Slab	7	23.35	*25.10*	25	3	3	23.35	28	22	Not Complied	Complied	Not Complied
2			23.98										
3			27.97										
1	4th Floor Slab	7	23.67	*26.42*	25	3	3	23.67	28	22	Not Complied	Complied	Not Complied
2			24.83										
3			30.76										
1	4th Floor Slab	7	25.48	*27.19*	25	3	3	25.48	28	22	Not Complied	Complied	Not Complied
2			26.43										
3			29.66										
1	4th Floor Slab	7	31.84	*31.91*	25	3	3	31.14	28	22	Complied	Complied	Complied
2			32.74										
3			31.14										
1	4th Floor Slab	7	23.49	*25.97*	25	3	3	23.49	28	22	Not Complied	Complied	Not Complied
2			27.78										
3			26.65										
1	4th Floor Slab	7	27.79	*26.05*	25	3	3	25	28	22	Not Complied	Complied	Not Complied
2			25.37										
3			25										
1	4th Floor Slab	7	23.34	*23.75*	25	3	3	22.95	28	22	Not Complied	Complied	Not Complied
2			22.95										
3			24.97										
1	4th Floor Slab	7	24.85	*23.08*	25	3	3	21.54	28	22	Not Complied	Not Complied	Not Complied
2			22.85										
3			21.54										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	5th Floor Slab	7	29.61	*27.67*	25	3	3	26.42	28	22	Not Complied	Complied	Not Complied
2			26.42										
3			26.99										
1	5th Floor	7	22.94	*21.25*	25	3	3	19.5	28	22	Not Complied	Not Complied	Not Complied
2			21.31										
3			19.5										
1	5th Floor Slab	7	20.83	*20.89*	25	3	3	19.52	28	22	Not Complied	Not Complied	Not Complied
2			22.32										
3			19.52										
1	5th Floor Slab	7	20.23	*20.26*	25	3	3	19.41	28	22	Not Complied	Not Complied	Not Complied
2			21.14										
3			19.41										
1	5th Floor Slab	7	19.48	*19.78*	25	3	3	19.07	28	22	Not Complied	Not Complied	Not Complied
2			20.8										
3			19.07										
1	5th Floor Slab	7	19.2	*20.25*	25	3	3	19.2	28	22	Not Complied	Not Complied	Not Complied
2			20.49										
3			21.07										
1	5th Floor	7	23.12	*22.66*	25	3	3	22.35	28	22	Not Complied	Complied	Not Complied
2			22.35										
3			22.5										
1	5th Floor Slab	7	24.08	*24.39*	25	3	3	21.58	28	22	Not Complied	Not Complied	Not Complied
2			21.58										
3			27.50										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1$=A	$f_{ck}-k_2$=B	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	5th Floor Slab	7	47.969	*44.14*	25	3	3	35.6	28	22	Complied	Complied	Complied
2			48.853										
3			35.6										
1	5th Floor Slab	7	20.25	*19.96*	25	3	3	17.35	28	22	Not Complied	Not Complied	Not Complied
2			17.35										
3			22.27										
1	5th Floor Slab	7	22.32	*20.13*	25	3	3	17.57	28	22	Not Complied	Not Complied	Not Complied
2			17.57										
3			20.5										
1	5th Floor Slab	7	17.92	*20.72*	25	3	3	17.92	28	22	Not Complied	Not Complied	Not Complied
2			23.46										
3			20.77										
1	Footing Pad	7	22.49	*21.62*	25	3	3	20.74	28	22	Not Complied	Not Complied	Not Complied
2			20.74										
3			21.62										
1	5th Floor Slab	7	19.16	*22.64*	25	3	3	19.16	28	22	Not Complied	Not Complied	Not Complied
2			23.6										
3			25.16										
1	5th Floor Slab	7	17.01	*18.86*	25	3	3	17.01	28	22	Not Complied	Not Complied	Not Complied
2			19.08										
3			20.49										
1	5th Floor Slab	7	25.56	*24.87*	25	3	3	22.34	28	22	Not Complied	Complied	Not Complied
2			22.34										
3			26.72										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	6th Floor Slab	7	30.61	*25.74*	25	3	3	20.34	28	22	Not Complied	Not Complied	Not Complied
2			26.26										
3			20.34										
1	6th Floor Slab	7	21.73	*21.03*	25	3	3	18.91	28	22	Not Complied	Not Complied	Not Complied
2			18.91										
3			22.45										
1	6th Floor Slab	7	39.12	*40.14*	25	3	3	35.18	28	22	Complied	Complied	Complied
2			35.18										
3			46.12										
1	6th Floor Slab	7	17.05	*18.82*	25	3	3	17.05	28	22	Not Complied	Not Complied	Not Complied
2			18.93										
3			20.47										
1	6th Floor Slab	7	22.32	*20.13*	25	3	3	17.57	28	22	Not Complied	Not Complied	Not Complied
2			17.57										
3			20.5										
1	6th Floor Slab	7	21.32	*21.85*	25	3	3	21.02	28	22	Not Complied	Not Complied	Not Complied
2			23.22										
3			21.02										
1	6th Floor Slab	7	23.49	*22.61*	25	3	3	21.81	28	22	Not Complied	Not Complied	Not Complied
2			22.53										
3			21.81										
1	6th Floor Slab	7	31.636	*24.93*	25	3	3	19.28	28	22	Not Complied	Not Complied	Not Complied
2			23.867										
3			19.28										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	6th Floor Slab	7	19.73	*20.33*	25	3	3	19.73	28	22	Not Complied	Not Complied	Not Complied
2			21.39										
3			19.88										
1	6th Floor Slab	7	24.88	*20.68*	25	3	3	16.48	28	22	Not Complied	Not Complied	Not Complied
2			16.48										
3			20.68										
1	6th Floor Slab	7	21.77	*19.79*	25	3	3	17.98	28	22	Not Complied	Not Complied	Not Complied
2			17.98										
3			19.63										
1	6th Floor Slab	7	21.75	*20.38*	25	3	3	18.94	28	22	Not Complied	Not Complied	Not Complied
2			18.94										
3			20.45										
1	6th Floor Slab	7	19.13	*19.98*	25	3	3	17.69	28	22	Not Complied	Not Complied	Not Complied
2			23.11										
3			17.69										
1	6th Floor Slab	7	17.35	*18.19*	25	3	3	17.2	28	22	Not Complied	Not Complied	Not Complied
2			17.2										
3			20.01										
1	6th Floor Slab	7	17.05	*18.82*	25	3	3	17.05	28	22	Not Complied	Not Complied	Not Complied
2			18.93										
3			20.47										
1	6th Floor Slab	7	30.911	*28.32*	25	3	3	24.41	28	22	Complied	Complied	Complied
2			29.653										
3			24.41										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	7th Floor Slab	7	17.71	*18.94*	25	3	3	17.71	28	22	Not Complied	Not Complied	Not Complied
2			19.32										
3			19.8										
1	7th Floor Slab	7	25.87	*20.36*	25	3	3	16.42	28	22	Not Complied	Not Complied	Not Complied
2			18.79										
3			16.42										
1	7th Floor Slab	7	17.73	*18.43*	25	3	3	17.73	28	22	Not Complied	Not Complied	Not Complied
2			18.5										
3			19.06										
1	7th Floor Slab	7	21.32	*21.85*	25	3	3	21.02	28	22	Not Complied	Not Complied	Not Complied
2			23.22										
3			21.02										
1	7th Floor Slab	7	21.91	*22.80*	25	3	3	18.91	28	22	Not Complied	Not Complied	Not Complied
2			18.91										
3			27.58										
1	7th Floor Slab	7	37.72	*33.65*	25	3	3	29.6	28	22	Complied	Complied	Complied
2			33.62										
3			29.6										
1	7th Floor Slab	7	20.28	*22.26*	25	3	3	17.03	28	22	Not Complied	Not Complied	Not Complied
2			17.03										
3			29.48										
1	7th Floor Slab	7	39.5	*29.42*	25	3	3	13.49	28	22	Complied	Not Complied	Not Complied
2			35.28										
3			13.49										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Top Tie Beam	7	18.618	*19.49*	25	3	3	17.02	28	22	Not Complied	Not Complied	Not Complied
2			22.818										
3			17.022										
1	Top Tie Beam	7	22.1	*18.70*	25	3	3	16.55	28	22	Not Complied	Not Complied	Not Complied
2			17.45										
3			16.55										
1	Top Tie Beam	7	17.61	*17.92*	25	3	3	17.61	28	22	Not Complied	Not Complied	Not Complied
2			18.21										
3			17.94										
1	Top Tie Beam	7	17.89	*18.10*	25	3	3	17.11	28	22	Not Complied	Not Complied	Not Complied
2			19.29										
3			17.11										
1	Top Tie Beam	8	16.27	*20.08*	25	3	3	14.45	28	22	Not Complied	Not Complied	Not Complied
2			29.53										
3			14.45										

Table 4.16. 28th Compressive Strength test results and analysis, according to EBCS-2 1995

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp. str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	28	30.72	*30.04*	25	3	3	28.41	28	22	Complied	Complied	Complied
2			28.41										
3			30.99										
1	Footing Pad	28	30.79	*29.87*	25	3	3	27.78	28	22	Complied	Complied	Complied
2			27.78										
3			31.03										
1	Footing Pad	28	30.6	*30.57*	25	3	3	29.3	28	22	Complied	Complied	Complied
2			29.3										
3			31.82										
1	Footing Pad	28	32.55	*32.94*	25	3	3	31.44	28	22	Complied	Complied	Complied
2			34.83										
3			31.44										
1	Footing Pad	28	31.41	*28.19*	25	3	3	26.01	28	22	Complied	Complied	Complied
2			26.01										
3			27.14										
1	Footing Pad	28	29.95	*29.44*	25	3	3	28.94	28	22	Complied	Complied	Complied
2			29.44										
3			28.94										
1	Footing Pad	28	28.36	*29.42*	25	3	3	28.36	28	22	Complied	Complied	Complied
2			30.36										
3			29.55										
1	Footing Pad	28	30.66	*28.97*	25	3	3	27.83	28	22	Complied	Complied	Complied
2			28.42										
3			27.83										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	28	35.98	36.02	25	3	3	34.47	28	22	Complied	Complied	Complied
2			34.47										
3			37.62										
1	Footing Pad	28	37.52	36.70	25	3	3	32.85	28	22	Complied	Complied	Complied
2			32.85										
3			39.74										
1	Footing Pad	28	33.53	33.88	25	3	3	32.23	28	22	Complied	Not Complied	Not Complied
2			32.23										
3			35.87										
1	Footing Pad	28	31.94	32.59	25	3	3	31.21	28	22	Complied	Complied	Complied
2			31.21										
3			34.62										
1	Footing Pad	28	36.73	36.78	25	3	3	35.35	28	22	Complied	Not Complied	Not Complied
2			35.35										
3			38.25										
1	Footing Pad	28	30.55	31.95	25	3	3	30.55	28	22	Complied	Not Complied	Not Complied
2			32.95										
3			32.35										
1	Footing Pad	28	36.11	37.35	25	3	3	36.11	28	22	Complied	Not Complied	Not Complied
2			36.94										
3			38.99										
1	Footing Pad	28	29.05	30.43	25	3	3	28.08	28	22	Complied	Not Complied	Not Complied
2			34.17										
3			28.08										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	28	31.82	*30.99*	25	3	3	29.97	28	22	Complied	Not Complied	Not Complied
2			29.97										
3			31.18										
1	Footing Pad	28	34.7	*33.35*	25	3	3	30.43	28	22	Complied	Complied	Complied
2			30.43										
3			34.92										
1	Footing Pad	28	28.82	*29.33*	25	3	3	28.82	28	22	Complied	Not Complied	Not Complied
2			29.92										
3			29.26										
1	Footing Pad	28	30.31	*29.03*	25	3	3	28.12	28	22	Complied	Complied	Complied
2			28.12										
3			28.67										
1	Footing Pad	28	30.26	*29.28*	25	3	3	27.58	28	22	Complied	Not Complied	Not Complied
2			30										
3			27.58										
1	Footing Pad	28	25.4	*27.17*	25	3	3	25.4	28	22	Not Complied	Not Complied	Not Complied
2			27.7										
3			28.42										
1	Footing Pad	28	31.69	*30.30*	25	3	3	29.05	28	22	Complied	Not Complied	Not Complied
2			30.16										
3			29.05										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Footing Pad	28	32.29	30.33	25	3	3	28.99	28	22	Complied	Not Complied	Not Complied
2			28.99										
3			29.7										
1	Footing Pad	28	51.644	48.10	25	3	3	44.62	28	22	Complied	Not Complied	Not Complied
2			44.622										
3			48.04										
1	Footing Pad	28	30.39	30.59	25	3	3	28.72	28	22	Complied	Not Complied	Not Complied
2			32.65										
3			28.72										
1	Footing Pad	28	31.73	32.38	25	3	3	29.47	28	22	Complied	Complied	Not Complied
2			29.47										
3			35.94										
1	Footing Pad	28	31.82	30.69	25	3	3	28.87	28	22	Complied	Not Complied	Not Complied
2			31.37										
3			28.87										
1	Footing Pad	28	32.64	32.67	25	3	3	29.64	28	22	Complied	Not Complied	Not Complied
2			35.72										
3			29.64										
1	Footing Pad	28	36.26	34.72	25	3	3	32.64	28	22	Complied	Complied	Complied
2			32.64										
3			35.27										
1	Footing Pad	28	37.17	37.23	25	3	3	36.69	28	22	Complied	Not Complied	Not Complied
2			36.69										
3			37.83										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	Ground Elevation Colum	28	34.96	35.38	25	3	3	34.96	28	22	Complied	Not Complied	Not Complied
2			35.37										
3			35.81										
1	Ground Elevation Column	28	28.11	31.23	25	3	3	28.11	28	22	Complied	Not Complied	Not Complied
2			31.73										
3			33.86										
1	Ground Elevation Column	28	52.578	54.36	25	3	3	52.58	28	22	Complied	Not Complied	Not Complied
2			55.6										
3			54.88										
1	Ground Elevation Column	28	27.38	29.28	25	3	3	27.38	28	22	Complied	Not Complied	Not Complied
2			31.15										
3			29.32										
1	Ground Elevation Column	28	34	32.59	25	3	3	31.22	28	22	Complied	Not Complied	Not Complied
2			31.22										
3			32.56										
1	Ground Elevation Column	28	28.61	27.71	25	3	3	27	28	22	Not Complied	Not Complied	Not Complied
2			27.00										
3			27.53										
1	Ground Elevation Column	28	30.35	32.15	25	3	3	30.35	28	22	Complied	Not Complied	Not Complied
2			34.94										
3			31.16										
1	Ground Elevation Column	28	31.35	29.09	25	3	3	27.29	28	22	Complied	Not Complied	Not Complied
2			28.63										
3			27.29										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	1st Floor Slab	28	32.48	*32.13*	25	3	3	30.87	28	22	Complied	Not Complied	Not Complied
2			30.87										
3			33.04										
1	1st Floor Slab	28	27.64	*27.92*	25	3	3	26.99	28	22	Not	Not Complied	Not Complied
2			29.13										
3			26.99										
1	1st Floor Slab	28	18.31	*24.14*	25	3	3	18.31	28	22	Not	Not Complied	Not Complied
2			28.72										
3			25.38										
1	1st Floor Slab	28	31.67	*28.37*	25	3	3	25.2	28	22	Complied	Complied	Complied
2			28.23										
3			25.2										
1	1st Floor Slab	28	29.99	*29.12*	25	3	3	27.33	28	22	Complied	Not Complied	Not Complied
2			27.33										
3			30.05										
1	1st Floor Slab	28	18.31	*24.14*	25	3	3	18.31	28	22	Not	Not Complied	Not Complied
2			28.72										
3			25.38										
1	1st Floor Slab	28	34.66	*30.30*	25	3	3	26.61	28	22	Complied	Not Complied	Not Complied
2			26.61										
3			29.63										
1	1st Floor Slab	28	32.8	*32.10*	25	3	3	31.53	28	22	Complied	Not Complied	Not Complied
2			31.96										
3			31.53										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str.	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2:
1	1st Floor Slab	28	27.57	*29.07*	25	3	3	27.57	28	22	Complied	Not Complied	Not Complied
2			30.57										
3			29.07										
1	1st Floor Slab	28	29.99	*29.12*	25	3	3	27.33	28	22	Complied	Complied	Complied
2			27.33										
3			30.05										
1	1st Floor Slab	28	30.72	*29.77*	25	3	3	28.92	28	22	Complied	Not Complied	Not Complied
2			28.92										
3			29.68										
1	1st Floor Slab	28	35.64	*38.25*	25	3	3	35.64	28	22	Complied	Not Complied	Not Complied
2			37.55										
3			41.55										
1	1st Floor Slab	28	35.09	*32.49*	25	3	3	30.3	28	22	Complied	Not Complied	Not Complied
2			32.09										
3			30.3										
1	1st Floor Slab	28	31.67	*32.81*	25	3	3	31.67	28	22	Complied	Not Complied	Not Complied
2			32.28										
3			34.47										
1	1st Floor Slab	28	49.511	*41.93*	25	3	3	31.16	28	22	Complied	Not Complied	Not Complied
2			31.16										
3			45.111										
1	1st Floor Slab	28	25.81	*29.85*	25	3	3	25.81	28	22	Complied	Not Complied	Not Complied
2			34.44										
3			29.31										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	2nd Floor Slab	28	28.4	27.99	25	3	3	24.85	28	22	Not Complied	Complied	Not Complied
2			24.85										
3			30.72										
1	2nd Floor Slab	28	36.17	27.62	25	3	3	22.24	28	22	Not Complied	Complied	Not Complied
2			22.24										
3			24.43										
1	2nd Floor Slab	28	28.62	27.33	25	3	3	25.58	28	22	Not Complied	Complied	Not Complied
2			27.79										
3			25.58										
1	2nd Floor Slab	28	26.65	28.18	25	3	3	26.17	28	22	Complied	Complied	Complied
2			26.17										
3			31.73										
1	2nd Floor Slab	28	27.67	28.36	25	3	3	27.67	28	22	Complied	Complied	Complied
2			28.44										
3			28.96										
1	2nd Floor Slab	28	29.11	27.68	25	3	3	25.77	28	22	Not Complied	Complied	Not Complied
2			28.15										
3			25.77										
1	2nd Floor Slab	28	31.49	28.89	25	3	3	26.35	28	22	Complied	Complied	Complied
2			26.35										
3			28.82										
1	2nd Floor Slab	28	35.09	32.49	25	3	3	30.3	28	22	Complied	Complied	Complied
2			32.09										
3			30.3										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str.	f_{ck}	k_1	k_2	x_1	f_{ck}+k_1=A	f_{ck}-k_2=B	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2:
1	3rd Floor Slab	28	34.13	*29.81*	25	3	3	25.96	28	22	Complied	Complied	Complied
2			29.33										
3			25.96										
1	3rd Floor Slab	28	29.89	*28.29*	25	3	3	25.69	28	22	Complied	Complied	Complied
2			25.69										
3			29.3										
1	3rd Floor Slab	28	29.63	*28.08*	25	3	3	27.08	28	22	Complied	Complied	Complied
2			27.54										
3			27.08										
1	3rd Floor Slab	28	25.06	*28.12*	25	3	3	25.06	28	22	Complied	Complied	Complied
2			31.18										
3			28.12										
1	3rd Floor Slab	28	47.44	*44.57*	25	3	3	37.68	28	22	Complied	Complied	Complied
2			37.68										
3			48.58										
1	3rd Floor Slab	28	27.098	*27.43*	25	3	3	24.14	28	22	Complied	Complied	Complied
2			31.04[illegible]										
3			24.14										
1	3rd Floor Slab	28	30.69	*29.08*	25	3	3	27.8	28	22	Complied	Complied	Complied
2			27.8										
3			28.75										
1	3rd Floor Slab	28	28.45	*29.14*	25	3	3	28.45	28	22	Complied	Complied	Complied
2			29.6										
3			29.36										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str.	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	4th Floor Slab	29	26.29	*27.74*	25	3	3	26.29	28	22	Not	Complied	Not Complied
2			28.9										
3			28.02										
1	4th Floor Slab	29	31.05	*30.98*	25	3	3	30.11	28	22	Complied	Complied	Complied
2			31.79										
3			30.11										
1	4th Floor Slab	29	32.31	*31.34*	25	3	3	30.28	28	22	Complied	Complied	Complied
2			30.28										
3			31.42										
1	4th Floor Slab	29	27.11	*29.04*	25	3	3	27.11	28	22	Complied	Complied	Complied
2			28.14										
3			31.86										
1	4thFloor Slab	30	37.97	*36.74*	25	3	3	35.99	28	22	Complied	Complied	Complied
2			36.27										
3			35.99										
1	4th Floor Slab	30	30.9	*29.35*	25	3	3	27.72	28	22	Complied	Complied	Complied
2			27.72										
3			29.42										
1	4th Floor Slab	30	30.01	*31.19*	25	3	3	30.01	28	22	Complied	Complied	Complied
2			30.9										
3			32.67										
1	4th Floor Slab	30	34.03	*33.19*	25	3	3	32.37	28	22	Complied	Complied	Complied
2			32.37										
3			33.18										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	5th Floor Slab	31	33.82	*32.01*	25	3	3	30.49	28	22	Complied	Complied	Complied
2			30.49										
3			31.72										
1	5th Floor Slab	35	28.08	*35.33*	25	3	3	28.08	28	22	Complied	Complied	Complied
2			41.51										
3			36.41										
1	5th Floor Slab	36	22.68	*25.75*	25	3	3	20.82	28	22	Not	Not Complied	Not Complied
2			33.74										
3			20.82										
1	5^{th} Floor Slab	39	32.93	*30.47*	25	3	3	28.19	28	22	Complied	Complied	Complied
2			30.28										
3			28.19										

Table 4.16. 45th Compressive Strength test results and analysis, according to EBCS-2 1995

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	6th Floor Slab	45	33.57	*32.59*	25	3	3	29.27	28	22	Complied	Complied	Complied
2			29.27										
3			34.94										
1	6th Floor Slab	45	33.89	*34.23*	25	3	3	32.55	28	22	Complied	Complied	Complied
2			32.55										
3			36.26										
1	6th Floor Slab	45	34.29	*32.31*	25	3	3	31.27	28	22	Complied	Complied	Complied
2			31.36										
3			31.27										
1	6th Floor Slab	45	32.55	*30.80*	25	3	3	28.99	28	22	Complied	Complied	Complied
2			30.87										
3			28.99										
1	6th Floor Slab	45	25.08	*26.66*	25	3	3	25.08	28	22	Complied	Complied	Complied
2			26.92										
3			27.97										
1	6th Floor Slab	45	27.73	*27.87*	25	3	3	27.15	28	22	Complied	Complied	Complied
2			27.15										
3			28.73										
1	6th Floor Slab	45	27.64	*30.20*	25	3	3	27.64	28	22	Complied	Complied	Complied
2			31.61										
3			31.36										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck}-k_2$	Decision According to EBCS-2: 1995
1	7th Floor Slab	45	34.53	*34.54*	25	3	3	32.86	28	22	Complied	Complied	Complied
2			32.86										
3			36.23										
1	7th Floor Slab	45	36.94	*40.19*	25	3	3	36.94	28	22	Complied	Complied	Complied
2			38.53										
3			45.09										
1	7th Floor Slab	45	37.34	*39.50*	25	3	3	37.34	28	22	Complied	Complied	Complied
2			43.07										
3			38.08										
1	7th Floor Slab	45	33.77	*38.79*	25	3	3	33.77	28	22	Complied	Complied	Complied
2			40.79										
3			41.82										
1	7th Floor Slab	45	31.4	*31.81*	25	3	3	30.21	28	22	Complied	Complied	Complied
2			33.82										
3			30.21										
1	7th Floor Slab	45	34.94	*33.96*	25	3	3	31.85	28	22	Complied	Complied	Complied
2			31.85										
3			35.08										
1	7th Floor Slab	45	33.16	*32.09*	25	3	3	30.86	28	22	Complied	Complied	Complied
2			30.86										
3			32.25										
1	7th Floor Slab	45	25.37	*27.59*	25	3	3	25.37	28	22	Complied	Complied	Complied
2			28.12										
3			29.29										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Top Tie Beam	45	33.58	*34.79*	25	3	3	33.58	28	22	Complied	Complied	Complied
2			36.33										
3			34.45										
1	Top Tie Beam	46	47.91	*39.45*	25	3	3	26.78	28	22	Not Complied	Complied	Not Complied
2			26.78										
3			43.67										
1	Top Tie Beam	46	30.49	*30.67*	25	3	3	30.23	28	22	Complied	Complied	Complied
2			30.23										
3			31.28										
1	Top Tie Beam	46	33.32	*32.18*	25	3	3	31.43	28	22	Complied	Complied	Complied
2			31.43										
3			31.79										
1	Top Tie Beam	47	25.35	*28.24*	25	3	3	25.35	28	22	Complied	Complied	Complied
2			28.92										
3			30.45										
1	Top Tie Beam	48	36.036	*34.74*	25	3	3	30.29	28	22	Not Complied	Complied	Not Complied
2			37.902										
3			30.293										

Sample No.	Sample Test Taken	Age (Days)	Compressive strength (Mpa)	Average Comp.str. (m_3)	f_{ck}	k_1	k_2	x_1	$f_{ck}+k_1=A$	$f_{ck}-k_2=B$	$m_3 >= f_{ck}+k_1$	$x_1 >= f_{ck} - k_2$	Decision According to EBCS-2: 1995
1	Top Tie Beam	7	17.85	*19.03*	25	3	3	17.85	28	22	Complied	Complied	Complied
2			21.30										
3			17.93										
1	Top Tie Beam	7	46.96	*38.53*	25	3	3	31.98	28	22	Not Complied	Complied	Not Complied
2			36.66										
3			31.98										
1	Top Tie Beam	7	42.83	*31.91*	25	3	3	22.03	28	22	Complied	Complied	Complied
2			22.03										
3			30.87										
1	Top Tie Beam	28	28.61	*28.92*	25	3	3	25.18	28	22	Complied	Complied	Complied
2			32.96										
3			25.18										
1	Top Tie Beam	28	34.08	*32.09*	25	3	3	30.30	28	22	Complied	Complied	Complied
2			30.30										
3			31.88										
1	Top Tie Beam	28	27.47	*29.27*	25	3	3	25.21	28	22	Not Complied	Complied	Not Complied
2			25.21										
3			35.12										

PART C

VIRTUAL CONSULTING PLC	Document No.: □F/V□P/216
INSPECTION CERTIFICATE	Issue No. 1 **Page 1 of 1**

Project: AAHCPO Low Cost Houses Project
Employer: Addis Ababa Housing Construction Project Office
Architect/Consultant: Virtual Consulting Plc.
Contractor:
Site Location: Koye Fetche II
Block:
Document Referred:

Check list title: **CONCRETE**

N.B The Architect's staff on site should mark the corresponding boxes with a tick, sign, file one copy and give back the other copy to the contractor.

		Confirming	Non Confirming	Not applicable
1.	Submittal of mix proportion for the mix design	☐	☐	☐
2.	Rechecking footing formwork from displacement of the fixed position, level and alignment	☐	☐	☐
3.	Spacer position	☐	☐	☐
4.	Rechecking the rigidity of the scaffolding and shuttering formwork from displacement of the fixed position	☐	☐	☐
5.	Leak tightness of joints between formwork element	☐	☐	☐
6.	Cleanliness of formwork	☐	☐	☐
7.	Cleanliness of lean concreted area	☐	☐	☐
8.	Surface condition of reinforcement	☐	☐	☐
9.	Diameter, location, spacing, required length, required number, shape, bonding dimension of the reinforcement both for footing and foundation			
10.	Proper positioning of foundation column reinforcement with the footing	☐	☐	☐
11.	Alignment of cantering of foundation column reinforcements	☐	☐	☐
12.	Method used for pouring concrete to avoid segregation/Chute, down pipe , trucking, or any other	☐	☐	☐
13.	Additional Remarks			

DECISION

The above items are fulfilled …… not fulfilled, the contractor is hereby allowed …../ refused ….. to clear the site. The take off sheet of this activity shall immediately be signed upon completion

For the Architect/Consultant		**For the Contractor**	
Name:		Name:	
Signature:		Signature:	
Date:		Date:	

	VIRTUAL CONSULTING PLC	Document No.: □F/VCP/216
	INSPECTION CERTIFICATE	Issue No. 1 Page 1 of 1

Project: AAHCPO Low Cost Houses Project
Employer: Addis Ababa Housing Construction Project Office
Architect/Consultant: Virtual Consulting Plc.
Contractor:
Site Location: Koye Fetche II
Block:
Document Referred:

Check list title: CONCRETE: Column or Grade Beam

N.B The Architect's staff on site should mark the corresponding boxes with a tick, sign, file one copy and give back the other copy to the contractor.

		Confirming	Non Confirming	Not applicable
1.	Checking of main reinforcement, stirrup and spacer from displacement of the fixed position, level and alignment	☐	☐	☐
2.	Conformity of the formwork with approved formwork design	☐	☐	☐
3.	Grout tightness and sufficiency of rigidity to prevent disturbance due to pressure of concrete, effect of vibrator and other load	☐	☐	☐
4.	Conformity of proper dimension for the finished surface	☐	☐	☐
5.	Provision of opening for maintaining pouring height of concrete with out segregation	☐	☐	☐
6.	Cleanliness, smoothness and treatment with release agent for the surface of formwork	☐	☐	☐
7.	The alignment of column along axis	☐	☐	☐
8.	Conformity for right dimension, vertical alignment and level of finished			
9.	Keeping the displacement of reinforcement with in the limit of tolerance	☐	☐	☐
10.	Additional Remarks			

DECISION

The above items are fulfilled …… not fulfilled, the contractor is hereby allowed …../ refused ….. to clear the site. The take off sheet of this activity shall immediately be signed upon completion

For the Architect/Consultant		**For the Contractor**	
Name:		Name:	
Signature:		Signature:	
Date:		Date:	

	VIRTUAL CONSULTING PLC	Document No.: DF/VCP/216
	INSPECTION CERTIFICATE	Issue No. 1 **Page 1 of 1**

Project: AAHCPO Low Cost Houses Project
Employer: Addis Ababa Housing Construction Project Office
Architect/Consultant: Virtual Consulting Plc.
Contractor:
Site Location: Koye Fetche II
Block:
Document Referred:

Check list title: Slab

PLACING OF CONCRETE

N.B The Architect's staff on site should mark the corresponding boxes with a tick, sign, file one copy and give back the other copy to the contractor.

		Confirming	Non Confirming	Not applicable
1.	Rechecking the level, cleanliness and smoothness of formwork from displacement of fixed position, level and alignment	☐	☐	☐
2.	Diameter, number, length, shape, bending dimension of main reinforcement bar in accordance with the drawing	☐	☐	☐
3.	Spacing, length and method of tying main bar	☐	☐	☐
4.	Cleanliness of all reinforcement bar (free from dir, paint. Oil, rust and other foreign substances	☐	☐	☐
5.	Deviation from the drawing in fixing and positioning of reinforcement	☐	☐	☐
6.	Overlap location an d length to be as shown on drawing	☐	☐	☐
7.	Type, shape, dimension, spacing and method of fixing of spacer to maintain the required concrete cover	☐	☐	☐
8.	Detail of all of reinforcement necessary for positioning and supporting structural reinforcement/number, length, diameter and shape for chair and spacing bars	☐	☐	☐
9.	Attention for positioning of top reinforcement in cantilever section/presence of bar fixer during placing of concrete for correction and positioning of reinforcement during placing of concrete	☐	☐	☐
10.	Provision of starter at location of hand rails for further welding and avoid chiselling of concrete on the waste of staircase	☐	☐	☐
11.	Approval of toilet seat fixture so that the exact position for the outlet can be identified	☐	☐	☐
12.	Provision of pvc pipes on the outlet position of toilets seats to avoid further chiselling	☐	☐	☐
13.	Proper positioning and fixing of electrical conduits and sanitary pies. /Note:- Approve the work permit under this titles before placing concrete./			
14.	Expansion joint	☐	☐	☐
15.	Sufficiency for different size of aggregates piled separately	☐	☐	☐
16.	Sufficiency of aggregates protected from contamination, minimized segregation	☐	☐	☐
17.	Prevention of intermingling aggregates with adjacent material	☐	☐	☐
18.	Provision of adequate drainage for the piled aggregates for maintaining uniform moisture content	☐	☐	☐
19.	Additional Remarks			

DECISION

The above items are fulfilled …… not fulfilled, the contractor is hereby allowed …../ refused ….. to clear the site. The take off sheet of this activity shall immediately be signed upon completion

For the Architect/Consultant		**For the Contractor**	
Name:		Name:	
Signature:		Signature:	
Date:		Date:	